UAB SCHOOL OF PUBLIC HEALTH

Department of Epidemiology

November 29, 2000

Dr. Mary S. Wolfe, Executive Secretary
NIEHS Mail Drop A3-07
111 TW Alexander Drive, Room A-329
Bldg 101 South Campus
Research Triangle Park, NC 27709

Re: 10th ROC Nominations: Solicitation of Public Comment—"Talc Containing Asbestiform Fibers"

In response to the referenced call for public comment, we are submitting herein written comments and are enclosing a copy of a report entitled, "Retrospective Follow-up Study of Mortality Patterns among Gouverneur Talc Company Workers." The report, which we issued in 1995, received peer review by several scientists. We are preparing two papers for publication based on the report and plan to submit the papers to a journal in January 2001.

The enclosed report describes the most recent analysis of mortality patterns among Gouverneur Talc Company (GTC) workers, a group that has been studied extensively over the past three decades. The report provides information related to the potential carcinogenicity of talc. We intend that this submission be considered by the National Toxicology Program (NTP) Board of Scientific Counselors' Subcommittee prior to the scheduled meeting on December 13-15, 2000.

Our study extended the follow-up period of previous investigations through the end of 1989 and incorporated several other improvements over previous research on GTC workers. In particular, our research:

- used, in addition to the United States general population, state and regional comparison groups;
- evaluated cause-specific mortality patterns by duration of employment and by time since first employment;
- estimated workers' quantitative exposure to total respirable dust; and
- analyzed lung cancer and nonmalignant respiratory disease mortality rates by estimated cumulative respirable dust exposure, using an internal referent group; these latter analyses reduce the possibility that results are due to confounding or observation bias.

Our study found that GTC workers, compared to the regional general population, had 2.3 times more than expected deaths from lung cancer (31 observed/13 expected deaths) and 2.2 times more than expected deaths from nonmalignant respiratory disease (28 observed/13 expected deaths). The lung cancer excess was concentrated in short-term employees and in underground

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miners. Millers, whose exposure to respriable dust was similar to that of underground miners, had only a small, statistically nonsignificant increase in lung cancer deaths. There was no, or an inverse, relation between cumulative respirable dust levels and lung cancer.

In contrast, an excess of nonmalignant respiratory disease deaths occurred both in short-term and in long-term workers and both in miners and in millers, and workers with cumulative dust exposure above the median had a higher mortality rate than other workers. In particular, decedents with pneumoconiosis or interstitial lung disease had median durations of employment and cumulative respirable dust exposure that were seven and 13 times higher, respectively, than the overall group of GTC workers.

We agree with the NTP that GTC workers clearly have increased mortality from lung cancer. However, several of our results argue against exposure to dust in GTC operations as the cause of the lung cancer excess:

- The lung cancer excess was concentrated in short-term workers, even when analyses were restricted to the employee subgroup with 20 or more years since hire (i.e., the subgroup with long induction time) (see our report, table III-8).
- The lung cancer excess was concentrated among underground miners (18 observed/4.1 expected, SMR=440, 95% CI=261-695), whereas millers, a group with estimated high exposure to dust, had an SMR for lung cancer of only 139 (7 observed/5.0 expected; 95% CI=56-287). Further, workers classified as unexposed to talc had a nonstatistically significant threefold increase in observed over expected lung cancer deaths (3 observed/0.97 expected, SMR=309, 95% CI=62-903) (see our report, table III-13).
- Lung cancer decedents had low estimated cumulative respirable dust exposure (median=297 mg/m^3-days) compared to the overall group of GTC workers (median=428 mg/m^3-days) (see our report, page 67 and table III-17), and cumulative respirable dust exposure levels were unrelated, or even inversely related, to lung cancer mortality rates (see our report, table III-16).

The lack of a dose-response gradient for estimated respirable dust exposure and lung cancer mortality rate ratios, along with the other results mentioned above, suggest that the overall increase in GTC workers is due, at least in part, to factors other than talc dust. The results do not support an interpretation that the talc dust in GTC operations is *per se* a lung carcinogen.

The NTP Review Group appears to have relied heavily on previous studies of GTC workers in determining if talc containing asbestiform particles is a human carcinogen. In reaching a final determination, we hope that the group will recognize that the various studies should not be considered as providing independent information on this topic. If, as several authors have suggested, the elevated lung cancer rate among GTC workers is due to an unidentified confounder (e.g., smoking, radon, other employment), the same confounder is likely to produce spurious results in all analyses of GTC employees, irrespective of the amount of follow-up time. Studies of truly independent groups (i.e., in Vermont and Norway), like studies of GTC workers, have yielded inconclusive evidence that talc ore dust is a lung carcinogen. In particular, the Vermont study, like our GTC study, found that the respiratory cancer excess was restricted to miners and did not affect millers and suggests that some feature of the mine environment rather than talc ore dust is implicated.

Thank you for the opportunity to add to the information about disease patterns among people exposed to talc being considered by the NTP.

Yours sincerely,

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A FOLLOW-UP STUDY OF MORTALITY PATTERNS AMONG GOUVERNEUR TALC COMPANY WORKERS

Submitted to

R.T. Vanderbilt Company

by

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SUMMARY

This investigation consisted of an exposure estimation survey and of a retrospective follow-up study of workers in the mining and milling operations of the Gouverneur Talc Company (GTC) in upstate New York. The broad objective was to determine if previously reported excesses of lung cancer and nonmalignant respiratory disease (NMRD) have persisted and if such excesses are caused by exposure to GTC talc dust.

The exposure estimation survey was conducted to develop a job-exposure matrix consisting of estimates of the average respirable concentration in each work area and calendar year covered by GTC talc operations. Estimates were developed using current average respirable dust concentration data, measured in two on-site surveys, and exposure scores, ranging from 1 (low) to 10 (high), representing both current and historical conditions and assigned by seven knowledgeable long-term GTC employees. Validation involved comparing the estimated concentrations with historical measurement data.

The job-exposure matrix included 11 "exposed" work areas and one "unexposed" work area. Operations in 8 of the 11 exposed areas covered 42 years (1948-1989), and three covered 16 years. Therefore, the final job-exposure matrix consisted of an estimated average respirable dust concentration for 384 "exposed" work area/year combinations. Two separate sets of estimates were developed. The first set was based on the scores of a single rater, selected because he was knowledgeable about both the

mining and the milling operations at GTC. The other was based on the scores of all seven raters.

The baseline (current) average respirable dust concentrations established from the on-site surveys indicated that levels were highest in mine 2-crushing (0.83 mg/m^3) and in mine 1-underground (0.73 mg/m^3); intermediate in mill 1 (0.35-0.53 mg/m^3) and mine 2-equipment operating (0.22 mg/m^3); and low in all other areas (0.06-0.14 mg/m^3).

The correlation between estimated and measured historical dust concentrations was judged to be acceptable (correlation coefficient = 0.78). On average, the job-exposure matrix estimates were 0.01 mg/m^3 higher than historical, measured exposures. Thus, use of the job-exposure matrix was expected to overestimate cumulative exposure among GTC workers. Nonetheless, cumulative exposure estimates, even if subject to this and random errors, would be useful for obtaining a relative ranking of subjects according to exposure for use in epidemiologic dose-response analyses.

The time period covered by the retrospective follow-up study was 1948 through 1989. The cohort included 818 subjects, for 97% of whom vital status was determined. The cohort's mortality rates were compared with the rates of the United States (US), New York (NY) and local general populations, using the standardized mortality ratio (SMR) as the measure of association. In addition, analyses using internal comparison groups were done to evaluate mortality patterns by estimated cumulative exposure.

These analyses used directly standardized rate ratios (RRs) to compare the lung cancer and nonmalignant respiratory disease (NMRD) mortality rates of cohort subgroups specified on the basis of estimated cumulative exposure levels.

The cohort had a total of 18,243 person-years of follow-up (median, 21 years per subject), a median duration of employment at the GTC of 2.0 years and a median age at hire of 27 years. Compared to US white men, GTC workers experienced a 41% increase in overall mortality (225 observed/160 expected deaths; SMR=141, 95% confidence interval=123-161). Excesses were present for most specific cause of death categories, including cancer (SMR=154, 115-200), circulatory disease (SMR=127, 103-155) and NMRD (SMR=293, 195-423). The circulatory disease increase was reduced substantially when the cohort's rates were compared with the local general population rates, whereas other increases persisted.

The cancer excess was due mostly to an elevated rate of lung cancer (31/12; SMR=254, 173-361). There also were increases in deaths from larynx cancer (2/0.49; SMR=410, 46-1481) and from lymphopoietic cancer (7/3.5; SMR=197, 79-407), but these were based on small numbers, were not statistically significant and could have been due to chance.

There were two deaths from mesothelioma, one reported previously in earlier investigations of GTC workers and the second newly identified in the present study. One of the two cases had worked in the GTC underground mine for 15 years and had relatively high estimated cumulative dust exposure. He also had worked in mining jobs for other employers before coming to the GTC. The second case probably worked at the GTC for less than one year, and he probably had, at most, minimal exposure to talc dust while at the GTC. However, he reportedly had worked on a construction project at another talc company for 7-8 years before his GTC employment began, and after leaving the GTC he operated a fuel oil business, in which his work may have entailed asbestos exposure. Experimental animal studies of GTC talc have not observed pleural tumors. For this reason, and because of the short amount of time between the first exposure and death of the first case and the, at most, low exposure of the second case, it is unlikely that either of the two mesotheliomas is due to GTC ore dust exposure.

The lung cancer SMR was nearly two times higher for subjects with <1 year worked than for subjects with 1+ years worked, and the SMR was directly related to time since hire. The lung cancer excess was concentrated among men who had worked only in the mines (18/3.8; SMR=473, 280-747). Men classified as unexposed to talc dust had a similar but statistically imprecise excess (3/0.69; SMR=433, 87-1264). Mill workers, in contrast, had only a minimal increase, consistent with random variability (7/4.7; SMR=150, 60-309).

The median estimated cumulative respirable dust exposure was 428 mg/m^3-days for the overall cohort, 730 mg/m^3-days for men employed in the underground mine and 686 mg/m^3-days for men in the mills. Lung cancer was inversely associated with estimated cumulative dust exposure (≥ median vs. < median: RR=0.66, 0.32-1.4). The lung cancer decedents had a median duration of GTC employment (0.86 year) and a median estimated cumulative dust exposure (297 mg/m^3-days) that were lower than the corresponding medians for the overall cohort.

The excess of NMRD was lower for pneumonia (7/3.3; SMR=214, 86-441) than for NMRD other than pneumonia (21/6.2; SMR=339, 210-518). The latter category included four decedents reported as having emphysema, seven as having pneumoconiosis or related conditions and 10 as having chronic obstructive pulmonary disease. NMRD increases were not associated strongly with years worked or time since hire. An excess of NMRD was present among subjects employed only in the mines (10/2.6; SMR=380, 182-698), only in the mills (11/3.2; SMR=347, 173-622) and in neither the mines nor the mills (6/3.0; SMR=202, 74-440). The latter increase was, however, limited in large part to pneumonia deaths. NMRD other than pneumonia (recorded as the underlying cause of death) was associated positively with estimated cumulative dust exposure (≥ vs. < median: RR=3.1, 1.1-9.7), although the dose-response trend was irregular. The "other" NMRD decedents had a median estimated cumulative dust exposure of 1202 mg/m^3-days, almost three times as high as that of the overall cohort. Seven NMRD decedents with pneumoconiosis or related conditions listed as the underlying cause of death had a median estimated cumulative dust exposure of 5806 mg/m^3-days. All but four of the other NMRD decedents had worked in mining or quarrying operations before coming to the GTC. Results were similar for analyses that combined the 21 decedents with other NMRD reported as the underlying cause of death with an additional 18 decedents having other NMRD as a contributory, but not underlying, cause.

The results of this study are similar to those of earlier investigations. The excess of lung cancer among GTC workers was moderately strong and was concentrated among men with long potential induction time, features that support a causal interpretation. However, several facts indicate that the association is not due to exposure to GTC talc dust.

The cohort giving rise to the lung cancer decedents had a rather high prevalence of smoking, and an excess of lung cancer was seen among subjects unexposed to GTC talc. These features suggest that some of the apparent increase is due to exposure to tobacco smoke. Mill workers and mine workers had similar estimated cumulative dust exposures, yet the excess of lung cancer was considerably stronger among miners than among millers. This indicates that GTC talc dust, per se, did not produce the excess. Most important, the presence of an inverse relationship between estimated cumulative exposure and lung cancer is inconsistent with the hypothesis that GTC talc dust is a carcinogen. The results of experimental animal studies also do not provide any support for this hypothesis.

The increased rate of NMRD among GTC workers may be due in part to confounding by smoking and employment in other dusty industries and in part to observation bias. However, some of the excess also may be attributable to exposure to GTC talc dust.

CONTENTS

BACKGROUND

The talc mines and mills of the Gouverneur Talc Company (GTC) are located in St. Lawrence County, New York (NY). The GTC started mining and milling operations in 1948, with the opening of one underground mine (mine 1) and one mill (mill 1). Mine 1 closed in 1995. Mill 1 is still in operation. In 1974, the GTC purchased the assets of International Talc, which included two mines (mines 2 and 3). Mine 2, an open pit mine, is still operating, whereas mine 3 shut down in 1976. The GTC also purchased four additional mills in 1974 (mills 2, 3, 6 and 6N). Mill 2 was never operated by the GTC and is presently used for storage. Mill 3 was used to process ore from mine 3 during 1975-1976 and then converted to Wollastonite processing. Part of mills 6 and 6N were used from late 1974 to mid 1976 to process ore from mines 1 and 2. These mills were then sold to another minerals processing company.

The GTC produces industrial-grade (tremolitic) talc. The talc ore from mine 1 is used primarily for ceramics. Product samples, evaluated by the National Institute of Occupational Safety and Health (NIOSH) in 1975, were reported to contain mineral talc (14-48%), as well as serpentine (10-15%), free silica (<2.6%) and the amphiboles tremolite (37-59%) and anthophyllite (4.5-15%) (1,2). Mine 2 ore is used primarily in paints. It is similar in composition to mine 1 ore except that it contains a higher percentage of fibrous talc, that is, talc containing particles that have dimensions consistent with the

NIOSH definition of a fiber (length of at least 5µm and length-to-diameter ratio of at least three to one, as determined by phase contrast optical microscopy)(3). Mine 3 produced a fibrous talc.

The underground mining and the milling operations at GTC have been described in detail by NIOSH (1,2). Environmental dust levels (breathing zone respirable dust concentrations), measured by NIOSH in 1975, ranged from an eight-hour time weighted average of about 0.05 milligrams per cubic meter (mg/m^3) for maintenance workers/mechanics to 1.60 mg/m^3 for muckers (1). The workplace exposure standard for respirable dusts which, like GTC ore dust, contain both talc and a high proportion of amphiboles and other minerals is 5 mg/m^3. The present ACGIH recommended threshold limit value (TLV) for respirable talc dust containing less than 1% free silica and no asbestos fibers is 2 mg/m^3 (4).

Mineralogically, the amphiboles (tremolite and anthophyllite) found in GTC ores are not asbestos (5-7). Crushing the ores, however, produces amphibole cleavage fragments, some of which are at least 5 µm long and have a length-to-diameter aspect ratio of three to one or greater. The carcinogenic potential of elongated nonasbestiform amphibole cleavage fragments has been the topic of considerable controversy, and the possibility that talc _per se_ is carcinogenic also has been investigated.

Several animal studies have evaluated the carcinogenicity of nonasbestiform amphiboles, including GTC mine ore, and of various forms of asbestos, using similar experimental designs (8-13).

Results of these investigations indicated that nonasbestiform amphibole minerals in general, and GTC talc ore in particular (8-10), did not increase the incidence of tumors, whereas asbestos was carcinogenic under the same experimental conditions.

Previous epidemiologic studies have evaluated the health effects of nonasbestiform amphiboles (14-17), of talc containing no or only trace amounts of nonasbestiform amphiboles (18-22) and of talc containing substantial amounts of nonasbestiform amphiboles (23-29). Each of the latter group of investigations included at least some GTC employees and are discussed later in this report.

Retrospective follow-up studies of workers exposed to taconite, which contains the nonasbestiform amphibole, cummingtonite-grunerite, reported no association with lung cancer or with nonmalignant respiratory disease (NMRD) (14,15). Investigations of gold miners exposed to silica, in addition to cummingtonite-grunerite and small amounts of tremolite-actinolite, found an increase in NMRD deaths but no excess of lung cancer (16,17).

Two follow-up studies of Italian miners and millers exposed to talc but not to amphiboles reported a deficit of lung cancer deaths (18,19). In these investigations, miners, who were exposed to silica in addition to talc, had a threefold increase in NMRD deaths; millers, who had high talc, but low silica, exposure did not experience such an excess.

A follow-up study of Vermont talc miners and millers, whose work did not involve exposure to silica or to amphiboles, reported slightly more than expected deaths from lung cancer (6 observed/3.69 expected deaths) and a sixfold increase in deaths from NMRD other than influenza and pneumonia (20). The lung cancer excess was present among miners (5 observed/1.15 expected deaths) but not among millers (2 observed/1.96 expected), despite the high likelihood that the talc exposures of miners had historically been lower than the exposures of millers. NMRD mortality was increased both in miners and in millers, with most of the NMRD deaths occurring in millers. These patterns indicated that the positive association with lung cancer among miners may have been due, not to talc exposure, but rather, to an unidentified attribute of the mine environment or of miners that was not shared with millers.

Norwegian talc workers exposed to ore containing talc and only trace amounts of silica, tremolite and anthophyllite have been reported to have an incidence of lung cancer close to that expected (21). These workers had a deficit of deaths from NMRD.

Thomas et al. reported a 2.5-fold increase in lung cancer deaths and a 2.2-fold increase in deaths from NMRD other than pneumonia and emphysema among pottery workers exposed both to silica and to talc that did not contain amphiboles (22). This study is of limited relevance to the issue of the carcinogenic potential of talc because it could not evaluate the effects of talc *per se*.

Investigations that included workers exposed to talc ore dust that may have contained appreciable amounts of amphiboles are summarized in table I-1 (23-29). The study by Kleinfeld et al. included nonGTC workers, as well as some GTC employees (23). It reported that the proportion of lung cancer deaths was three times higher among NY talc workers than in the general United States (US) population.

The other five studies included only GTC workers (24-29). Four of these were follow-up studies (24-28) that differed from one another in terms of the numbers of subjects and the length of the follow-up period. All four reported an excess of deaths from lung cancer and from NMRD. In three of the four follow-up studies GTC workers had a greater than twofold increase in deaths from both of these diseases (24,25,27,28). In one of the studies the excesses were considerably smaller (26). The explanation for this inconsistency is unknown.

Data on lung cancer mortality by duration of employment, available from two recent GTC follow-up studies (27,28), were consistent with, respectively, an inverse or no duration-response relationship. Lamm et al. (27) reported a lung cancer SMR of 316 (95% confidence interval (CI)=116-687, observed deaths=6) for short-term (<1 year) workers and an SMR of 193 (CI=71-420, observed=~~1~~6) for long-term (1+ years) workers. Brown et al. (28) reported results for lung cancer that indicated no meaningful difference in the SMRs of short-term (SMR=222, CI=96-438, observed=8) and long-term workers (SMR=196, CI=89-369, observed=9).

Lamm et al. (27) noted that 5 of the 12 GTC workers with lung cancer had been very short-term employees, with overall durations of employment of 3 months or less, and that 4 of the remaining lung cancer decedents had worked for only 11 months to 3.8 years. They further suggested that the observed association between GTC employment and lung cancer was noncausal, and that the elevated lung cancer SMR among GTC workers may have been attributable in large part to pre-GTC employment, smoking or other behavioral characteristics rather than to GTC talc exposure.

NIOSH conducted a case-control study of lung cancer among GTC workers that addressed the problem of potential confounding and that further examined lung cancer risk in relation to length of work (29). Data from the study indicated that there was no, or an inverse, relation between duration of employment at GTC and lung cancer among smokers and that nonGTC occupational history did not appear to be a confounder of this relation.

In the follow-up studies of GTC workers, the pattern of NMRD deaths by employment duration differed to some extent from the pattern seen for lung cancer, in that there was some suggestion of an increase in the SMR for NMRD with increasing duration of employment (27,28). In the Lamm et al. study, the NMRD SMRs were 176 (CI=36-516, observed=3) and 278 (CI=111-572, observed=7) for short- and long-term workers, respectively (27). The increase among short-term workers was due entirely to an excess of pneumonia deaths, whereas the larger excess among long-term workers was attributable to noninfectious NMRD. NIOSH reported similar results (short-term workers: SMR=194, CI=72-428, observed=6; long-term workers: SMR=289, CI=145-518, observed=11) for all NMRD combined but did not evaluate subcategories of NMRD (28). Because the number of NMRD deaths was small in these analyses, the results were rather imprecise, and the trends were not statistically significant.

Each of the four follow-up studies of GTC workers had limitations that made interpretation of their positive results unclear. These included small study size and consequently imprecise measures of association; poor exposure estimation (years worked at GTC was used as a surrogate for talc dust exposure); lack of data on smoking, an important potential confounder of the association between talc exposure and lung cancer mortality; and lack of information on occupational history, another possible confounder. The case-control study controlled for potential confounding but did not analyze lung cancer risk as a function of estimated cumulative dust exposure.

In summary, previous research indicates that GTC employees have an excess of NMRD that may be due, at least in part, to talc ore dust exposure. The interpretation of the observed lung cancer increase among these workers remains uncertain. The absence of a clear, positive duration-response trend and the fact that a large proportion of the observed lung cancer decedents had worked for a short period of time at the GTC argue against a causal association. A further investigation of GTC workers, including an extension of the follow-up period and an analysis of lung cancer and NMRD mortality patterns by estimated dust exposure levels, was undertaken in order to obtain more information on the experience of the relatively small subcohort of long-term employees and on dose-response relationships. The investigation consisted of two parts. The first was an exposure estimation survey, designed to develop a job-exposure matrix to be used in estimating GTC subjects' cumulative exposure to respirable dust. The second was a retrospective follow-up study evaluating the impact of various employment factors and of cumulative respirable dust exposure on mortality patterns among GTC employees.

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Table I-1

Mortality studies of GTC talc workers

Reference	Study Design/ follow-up period	Subgroup	Lung cancer Obs*	Lung cancer SMR, OR or PMR#	Lung cancer 95% CI	Nonmalignant respiratory diseases Obs	Nonmalignant respiratory diseases SMR or PMR	Nonmalignant respiratory diseases 95% CI
Kleinfeld et al.¶ (23)	n=180 (deaths, only); worked ≥ 15 years; employed 1940-1969; FU; 1940-1969	Overall	13	324 (PMR)	-	29§	-	-
Brown et al. (24,25)	n=398; ever worked 1947-1959; FU; 1947-1975	Overall	9	273	125-518	8	276	119-544
		Worked: ≤ 1 yr	5	-	-	-	-	-
		> 1 yr	4	-	-	-	-	-
Stille, Tabershaw (26)	n=655; ever worked 1948-1977; FU; 1948-1978	Overall	10	157	75-287	10	164	79-301
Lamm et al. (27)	n=705; ever worked 1947-1977; FU; 1947-1978	Overall	12	240	124-419	10	236	113-435
		Worked: < 1 yr	6	316	116-687	3	176	36-516
		1+ yr	6	193	71-420	7	278	111-572
Brown et al. (28)	n=710; ever worked 1947-1978; FU; 1947-1983	Overall	17	207	121-332	17	246	144-394
		Worked: < 1 yr	8	222	96-438	6	194	72-428
		1+ yr	9	196	89-369	11	289	145-518
Gamble (29)	22 lung cancer cases, 66 controls from the cohort in ref.27; controls matched to cases on birth and hire dates	Smokers only:						
		Worked: < 5 yr	12/22	1.00 (OR)				
		5-15 yr	2/5	0.63 (OR)				
		≥ 15 yr	4/15	0.43 (OR)				

* Observed number of deaths for refs. 23-28; no. cases/no. controls for ref. 29.

\# SMR, standardized mortality ratio; PMR, proportional mortality ratio; OR, odds ratio. The value reported is the SMR if not specified as a PMR or an OR.

¶ Includes nonGTC talc workers.

§ Pneumoconiosis and complications only.

EXPOSURE ESTIMATION SURVEY

OBJECTIVES

The purpose of the exposure estimation survey was to develop a job-exposure matrix covering all GTC work areas during the entire study period. The matrix consisted of an estimate of the average respirable dust concentration in each work area and each calendar year during the period 1948 through 1989. The estimated dust concentrations were derived from exposure scores, ranging from 1 (low) to 10 (high), for each work area and year and from reference dust concentrations measured in surveys intended to determine average concentrations under current operating conditions. The matrix was linked with cohort work histories to estimate the cumulative exposure to respirable dust of each subject in the retrospective follow-up study.

METHODS

Overview of exposure estimation procedures

Table II-1 displays the available GTC ore dust exposure measurements by year and type (dust count, fiber count, respirable dust, total dust). Measurements were available for a limited number of GTC jobs/work areas and time periods. Also, some of the measurements were not used in the present study because of uncertainty regarding the source, type or location of the sample or because the sample appeared to be an outlier (i.e., the concentration was extremely high).

Because of the sparse availability of the historical data, cumulative respirable dust exposure estimation for individual subjects could not be based exclusively on existing dust measurements. Rather, we developed a job-exposure matrix consisting of estimates of respirable dust concentrations for various work area and calendar year combinations. In brief, job-exposure matrix development included: 1) specifying work areas and component jobs, 2) defining time periods during which exposure levels could be considered uniform within the work areas and assigning an exposure score to each work area/time period, 3) conducting special surveys to determine current exposure conditions in the work areas and to develop a factor for converting historical dust count data to respirable dust concentrations, 4) estimating historical respirable dust concentrations for each work area/calendar year category, and 5) validating the job-exposure matrix estimates by comparing actual historical measurements with estimated concentrations. Respirable mass, rather than dust count, data were used as the basis of cumulative exposure estimates because of the better precision of respirable mass sampling and analytical methods and the necessity of pooling data collected by several agencies.

Work area specification

Each job title included in the work histories of GTC employees was assigned to a work area. A work area was defined as a group of jobs having similar work environments (1). The work area job groups were based on classifications developed by NIOSH as part of preliminary work for a later report (2). The final groups were specified by the project industrial hygienist, in consultation with long-term supervisory personnel familiar with operating conditions at GTC. Jobs comprising a given work area were assumed to be reasonably homogeneous with respect to exposure within specified time periods.

Originally, we considered 14 work areas (Appendix A). We reduced the number to 11 by combining three minimal exposure areas (i.e., in the mills, in mine 1 and in unspecified areas) and two underground mine areas (drilling and other underground mining). We then added a "mill average" area, consisting of laborers who worked in unspecified areas within the talc mills. The final 12 work areas and typical job activities within each area are shown in Table II-2.

Specification of time periods and development of scores

Work area-specific uniform exposure time periods were defined as calendar periods during which non-random, deterministic variables, such as operating processes and control technology, were constant, and during which the average exposure level probably did not change over time (3). These periods were specified by a panel of three knowledgeable GTC supervisory personnel assembled for the previous NIOSH study (2), using production records, dust control information and past environmental reports. The UAB project industrial hygienist reviewed this information and judged the time period specification to be adequate. The same group of GTC supervisory personnel (the "NIOSH panel"), along with five additional long-term GTC employees, assigned an exposure score, ranging from 0 for no exposure, to 10 for highest exposure, within each time period to the most commonly held jobs comprising a given work area.

The NIOSH panel included three salaried long-term employees: rater 1, hired in 1953 and familiar with both the mines and the mills; rater 2, hired in 1948 and familiar with the mills; and rater 3, hired in 1971 and familiar with the mines. The five additional GTC personnel selected to assign exposure scores for the present study included: rater 4, hired in 1951 and familiar with the mills; rater 5, hired in 1954 and familiar with the mills; rater 6, hired in 1957 and familiar with the mills; rater 7, hired in 1950 and familiar with the mines; and rater 8, hired in 1959 and familiar with the mines. Raters 4 through 8 had all been hourly paid employees.

Rater 1 assigned scores to all jobs and years. Because of their different hire dates and different work experiences, all the other raters assigned scores only to selected jobs within selected work areas and "locations" (mill, mine 1, mine 2) and only for selected years. Rater 6 provided extremely incomplete information, and we discarded his scores.

We developed two types of average scores in order to evaluate inter-rater agreement and to carry out exposure estimation. First, each rater's job/year-specific scores were averaged over all jobs comprising a given work area to obtain a "work area/year" score. Second, work area/year-specific scores were averaged over all work areas within a location and over all years within a time period to obtain a mean "location/time period score." Time periods were specified on the basis of the number of raters providing scores. For example, in some time periods, only two raters provided scores for a given location, whereas in other time periods three or four raters provided scores.

We evaluated inter-rater agreement among the scores separately for the three major GTC locations (i.e., the mills, mine 1 and mine 2). This was necessary because of differences among the raters in the locations and time periods about which they were knowledgeable.

Inter-rater agreement among the absolute values of the work area/year-specific scores was poor, although raters tended to agree on trends over time in exposure levels for a given work area. That is, there tended to be a constant difference between a work area/year-specific set of scores for two raters. For example, when one rater scored a given work area as "9" in 1948-1959, "7" in 1960-1969 and "5" in 1970-1989, another rater may have assigned to the same work area scores of "7," "5" and "3," respectively, for the three time periods. In this example, the absolute values of the first rater's scores differed by a constant amount of 2 from the second rater's scores within each time period, and the raters agreed on the trend of decreasing exposure levels with advancing calendar time.

To evaluate inter-rater agreement among the trends, we first computed a rater's "residual" score for each combination of work area, location and time period by subtracting the rater's mean location/time period score from each component work area/year-specific score. Using analysis of variance, we then evaluated the effect of calendar year, rater and work area on the entire set of residual scores available from all raters for each location and time period (4).

The evaluation of inter-rater agreement, presented in the results section, indicated that it would be appropriate to compute summary scores for each work area/year category, averaging across all raters who provided relevant information for the specific category after adjusting for the constant difference among raters' scores, referred to above. To obtain the average "adjusted" scores, we first designated the scores of rater 1 as the "standard" or reference set of scores. Rater 1 was chosen as the standard because he had extensive experience in both the mines and the mills and was judged to be the most knowledgeable of the raters. Next, we computed each rater's "adjusted score" for a given location/work area/year-specific category as his actual score, minus the difference between his and the standard rater's mean location/time period-specific scores. We then obtained the average adjusted score for each work area/year-specific category by summing the adjusted scores of all raters contributing data to that category and dividing by the number of raters.

Finally, we computed for rater 1 and for the seven raters: 1) a "mill average" score for laborers who worked in unspecified areas within the mills as the year-specific mean of rater 1's scores or the adjusted average scores for milling, packing, packhouse support and maintenance; 2) an "underground mining" score as the year-specific mean of rater 1's or the adjusted average scores for drilling and other underground mining: and 3) a "minimal exposure" score as the year-specific mean of rater 1's or the adjusted average scores for all three minimal exposure areas in the GTC mines and mills.

Special exposure surveys

Two one-week exposure surveys were conducted by the project industrial hygienist and a research assistant to measure current respirable dust concentrations during warm- and cold-weather months and to develop a factor to convert historical dust count data to respirable dust concentrations. The first survey was conducted on July 29 through August 2, 1991, and the second survey was conducted on December 9 through December 13, 1991.

Personal air samples were collected and analyzed to determine time-weighted average respirable dust concentrations according to NIOSH Analytical Method 0600 - Nuisance Dust, Respirable (5). Impinger samples for dust counts were collected and analyzed according to the US Public Health Service Impinger Sampling Technique (6). Area samples for respirable dust were collected using a cyclone that had the necessary aerodynamic cut size while sampling at a flow rate of 9 L/min (7); these samples were also analyzed by NIOSH Method 0600 (5). The use of the high volume cyclone allowed identical sampling times for the impinger and respirable dust samples. Impactor samples were collected and analyzed according to the manufacturer's instructions, and respirable mass fraction was calculated from the observed particle size distribution (8). Area and impactor samples were collected at fixed locations in close proximity to the designated job title.

Coincident respirable dust and dust count samples were used to generate a factor for converting historical dust count data to respirable dust concentrations. When available, paired respirable dust and dust count data collected during the NIOSH survey of 1975 (2) were included in the data set used to develop the conversion factor. A weighted regression equation of the natural logarithms of the respirable dust and the dust count concentrations was used to convert historical dust count data, provided by GTC, to respirable dust concentrations. Based on corresponding descriptive information, the historical dust concentration data were classified into the previously described work area/year matrix. The average of the historical measurements was then calculated from the data available for each work area/year category for use in the validation procedure.

Estimation of work area/time period-specific dust levels

Quantitative dust concentration estimates were developed for each work area-time period combination as follows. First, the "baseline" arithmetic mean (9) respirable dust concentration for each work area was derived from data collected in the two exposure surveys conducted by UAB and from data collected in the NIOSH survey. Baseline concentrations were intended to represent exposure conditions in 1985-1989. The NIOSH data were included in calculating the mean baseline concentration of a work area if there was no marked difference between the data collected in the UAB surveys and the NIOSH survey. Based on this criterion, the NIOSH data were included in the current mean concentration estimates for three work areas. The purpose of incorporating the NIOSH data was to reduce the confidence interval for the estimate of the mean concentration.

Next, for each time period, the estimated average respirable dust concentration for the work area was computed as the product of the baseline mean concentration and the ratio of the time period-specific exposure score to the baseline exposure score. This computation is illustrated in the following conceptual equation:

$$\textit{Estimated Dust Conc} = \textit{Baseline Dust Conc} \times \frac{\textit{Time Period-Specific Exposure Score}}{\textit{Baseline Exposure Score}}$$

We developed two sets of estimates, one based only on the scores of rater 1, and the other based on the average adjusted scores. Rater 1 was the only rater familiar with both the mines and the mills and was perceived to be the most knowledgeable of the raters regarding GTC operations. Therefore, more confidence was accorded to estimates based on his scores. We carried out subsequent validation analyses (see below), as well as cumulative exposure estimation and related epidemiologic analyses for subjects in the retrospective follow-up study, separately for the two sets of scores. All results were similar for the two sets, and only those based on the scores of rater 1 are presented in this report.

Validation of exposure estimation procedures

We validated the exposure estimation procedures by comparing work area/year-specific exposure estimates with the mean of the historical dust measurements, available for selected work areas and years. The use of the latter data was complicated by the fact that dust samples were collected by several agencies using diverse methods, including R.T. Vanderbilt Inc., environmental consultants and/or insurance carriers, state and Federal safety and health regulatory agencies, and NIOSH. The use of pooled data collected by different agencies could produce information bias (10,11). Particularly, regulatory agencies tend to overestimate the average dust level by conducting compliance or "worst case" sampling (12). This bias may also be present in data collected by insurance carriers, and even in some data collected by company hygienists. Also, the precision of the historical data was limited because most of the data were converted from dust counts to respirable mass concentrations by a regression equation with a moderate coefficient of determination.

RESULTS

Work area/job categories

Table II-2 lists the 12 work areas designated for this study and the typical job activities within each area. Appendix B contains the complete list of job titles by work area. Table II-2 also summarizes the availability of scores and of baseline dust concentrations for the various work areas and component jobs.

Exposure scores

As indicated previously, the number of raters contributing scores varied by location and time period (Table II-3). For the mills, the number of raters contributing scores was 2 for the period 1948-1953, 3 for 1954-1957 and 4 for 1958-1985. For mine 1, the number of raters was 2 for 1948-1958, 3 for 1959-1970 and 4 for 1971-1985. For mine 2, 3 raters provided scores covering the period 1974-1985. The results of the regression models used to evaluate inter-rater agreement among the residual scores indicated that, for each location and time period, the scores did not vary significantly by rater (Table II-3). In contrast, both work area within the location and year within the time period were statistically significantly associated with the scores. Tables II-4 and II-5 display, respectively, the work area/year-specific scores of rater 1 and the seven raters' average adjusted scores. Differences between the two sets of scores tended to be unremarkable.

Exposure surveys

Baseline dust concentrations

Table II-6 presents the personal, area and impactor exposure data collected during the two special exposure surveys conducted by UAB. For all measurements, the respirable dust concentrations ranged from 0.01 to 2.67 mg/m^3, with an arithmetic mean of 0.47 mg/m^3, a geometric mean of 0.28 mg/m^3, and a geometric standard deviation of 3.05. The geometric mean of the measurements made during the summer survey was 0.59 mg/m^3, whereas that for the winter survey was 0.41 mg/m^3. These values were not significantly different. Therefore, no adjustment was made for seasonal differences in the subsequent data analysis or exposure estimation.

Of the work areas that included large numbers of employees, mill 1-packing had the highest arithmetic and geometric mean exposures, followed by mine 1-underground. Mill 1-milling had a high arithmetic mean (0.58 mg/m^3), but a relatively low geometric mean (0.29 mg/m^3). This difference was due to four observed concentrations greater than 1.0 mg/m^3, and is reflected by a high geometric standard deviation of 3.80.

Table II-7 displays the arithmetic and geometric mean baseline dust concentrations developed from the special survey data and, for work areas 4 through 6, from combined special survey and NIOSH data. The use of data from the UAB and NIOSH surveys for these work areas indicates that exposure levels in these areas did not significantly change between 1975 and 1991. Exposure levels were relatively high in mine 2-crushing (0.83 mg/m^3) and in mine 1-underground (0.73 mg/m^3); intermediate in mill 1 (0.35-0.53 mg/m^3) and mine 2-equipment operating (0.22 mg/m^3); and low in all other areas (0.06-0.14 mg/m^3).

Conversion of dust counts

Historical dust counts were converted to respirable mass concentrations using the regression equation produced from 50 paired impinger and respirable mass samples. Previous studies have reported an average ratio for this type of conversion (13-15). However, the set of ratios in this study was found to be log-normally distributed, so a regression equation using the natural logarithms of measured dust counts and respirable mass concentrations was thought to be a more appropriate method of conversion. The weighted regression equation, shown below, yielded a correlation coefficient of 0.78:

$$\ln(mg/m^3) = \ln(mppcf) * 0.3255 - 0.8529.$$

The natural logarithms of the 50 coincident dust count and respirable mass samples with the regression line are shown in Figure 1.

Work area/year-specific dust concentration estimates

Table II-8 presents work area/calendar year-specific estimates of average respirable dust concentrations, computed using the scores of rater 1 and the baseline respirable dust concentrations. Exposure concentrations were estimated to be slightly higher in milling than in underground mining until the early 1970s, and were estimated to be similar in the two locations or slightly higher in underground mining than in milling thereafter.

Validation of historical dust concentration estimates

Table II-9 summarizes the years and work areas for which converted, historical respirable dust measurements were available (n = 45) and the corresponding predicted exposures from the estimation procedure described above. The data also are plotted in Figure 2. The correlation coefficient for the measured and predicted exposures was 0.73. The average bias for the predicted exposures was -0.01 mg/m^3 (16): on average, the predicted exposures were 0.01 mg/m^3 higher than the historical measured exposures. Bias within the work areas ranged from 0.17 mg/m^3 in mine 1-surface crushing to -0.32 mg/m^3 in mine 2-crushing.

DISCUSSION

A job-exposure matrix based on work area and time was developed to estimate historical exposures of the cohort to respirable talc dust in the GTC facilities. The use of an exposure matrix was thought to be the most effective method of estimating exposures given the quantity and quality of available exposure data. This method is much more sensitive than ordinal classification of exposures, and it avoids the uncertainties of exposure prediction models (16). The utility of the job-exposure matrix was enhanced by the availability of categorical exposure scores assigned by qualified observers. These scores, along with the determination of baseline exposure concentrations for the work areas, made it possible to estimate year-specific respirable dust exposure concentrations for the years 1948 through 1989.

It had been proposed initially to use dust count data as a parallel estimate of exposure to talc dust. However, it was decided to use respirable dust concentrations because these data were considered to be more precise than dust count data (17,18) and less biased than some of the historical data (10, 11). The use of UAB and NIOSH respirable dust concentration data also avoided any increased imprecision resulting from converting these data to dust counts by a regression equation that had a correlation coefficient of 0.78. The effect of the imprecision of the conversion was limited to those respirable dust concentrations which were converted from historical dust counts and used to validate the exposure estimates.

No attempt was made to use available fiber count data because of inconsistencies between the regulatory and mineralogic definitions of fibers and the mineralogic composition of talc dust at GTC. According to the NIOSH analytical method for asbestos, a fiber is defined as any particle with a length-to-width aspect ratio of at least 3:1 and a length of 5 µm or more observed under phase contrast microscopy (19). However, this definition has been criticized by mineralogists as being nonspecific for true asbestisform fibers (20). Kelse and Thompson have demonstrated that airborne cleavage fragments of nonasbestisform tremolitic talc dust collected at GTC would be incorrectly classified as fibers under the 3:1 aspect ratio rule (21). This misclassification resulted in an overestimation of fiber counts in air samples collected at that facility.

The development of the job-exposure matrix involved a number of assumptions and uncertainties. The definition of the work areas used in this study began with those specified by NIOSH in the preliminary work for their 1990 report (2). However, modifications were made based on an evaluation of the operational characteristics of the areas, on statistical analysis of UAB and NIOSH respirable dust data and on the availability of exposure rating scores for jobs assigned to the areas. Work area 1 (mill 1-average) was developed to define exposures for laborers who worked in the mill but who could not be assigned to a specific work area. Observation of packing operations indicated that there were distinct differences between activities of packers/palletizers and other jobs in this area. A two sample t-test found that there was a significant difference between the mean natural logarithms of the respirable dust concentration for these two groups (α = 0.05). Therefore, a work area for packhouse support was assigned. It was also considered whether drillers should comprise a work area separate from other jobs in mine 1-underground. A two sample t-test found that there was no significant difference between the mean natural logarithms of the respirable dust concentration for these two groups (α = 0.05), so a single underground work area was retained. Mine 2 was not in operation when NIOSH conducted their survey in 1975, so these work areas were defined on the basis of differences among operational characteristics and supported by measured dust exposures.

The arithmetic means of UAB and NIOSH respirable dust concentrations were used to define baseline exposures in each area, and consequently, to calculate estimated exposures for the job-exposure matrix. These values were used because the accumulated uptake of the contaminant by the human body is proportional to the arithmetic mean of the period under observation (9,10). The value for mill 1-average was the arithmetic mean of all observations in work areas 2 through 5. The value for the minimal exposure group was taken as the exponent of the 5^{th} percentile of natural logarithms of exposures used to define baseline values for all work areas. In some work areas, the baseline exposure are based on very few samples ($n \leq 4$), so the true average could be within a relatively large range.

As indicated in Table II-9, historical data were available for 8 of the 11 "exposed" work areas but tended to be clustered in specific years. Therefore, the validation of the estimated exposures was limited to only 45 of the 418 cells of the job-exposure matrix (10.8%). Also, in some cases, the number of measured, historical exposures in a cell is very small.

The observed correlation coefficient of measured and estimated exposures was considered to be good given the following characteristics of the data: 1) the inherent variability of the dust count method (16,17); 2) the relatively low correlation coefficient for the conversion of dust counts to respirable dust exposures; 3) the use of pooled data collected by several agencies using different methods (10); and 4) the use of averages of a small number of observations to represent exposures which are known to exhibit considerable inter- and intra-day variation (9). The average bias of only -0.01 mg/m^3 was quite remarkable, given the above characteristics of the data. The wide range of average bias among the work areas is probably an indication of the instability of this number. A detailed statistical validation of the predicted exposures was not conducted because of the relatively small number of cells. However, it is noted that the average bias for each work area is well within a factor of one of the mean value for that area.

The estimated exposures in this study do not take into account other factors which affect the uptake of contaminants. These factors could include: 1) the effective use of respiratory protection, 2) part-time exposures, 3) personnel rotation not recorded in administrative work histories, 4) unfavorable distribution of exposure periods over time, and 5) unusually hard work increasing the ventilation of the exposed individuals (9). Of these, the use of respiratory protection would be the most likely uptake modifier among GTC employees. It was observed that there is current wide-spread usage of respirators, but it is not known when the use of this equipment was initiated, or how conscientiously and effectively it is used.

In summary, it is expected that the concentrations in the job-exposure matrix would over-estimate the actual exposures experienced by GTC employees. This is based on a slight average negative bias of estimated exposures when compared to historical data which are thought to represent worst-case conditions (12). Also, the estimated exposures do not take into account the diminishing effect of respiratory protection.

For these reasons, the absolute values of cumulative exposure estimated for subjects in the retrospective follow-up study may not be accurate. However, cumulative exposure estimates should be useful for obtaining a relative ranking of subjects according to exposure for use in epidemiologic dose-response analyses.

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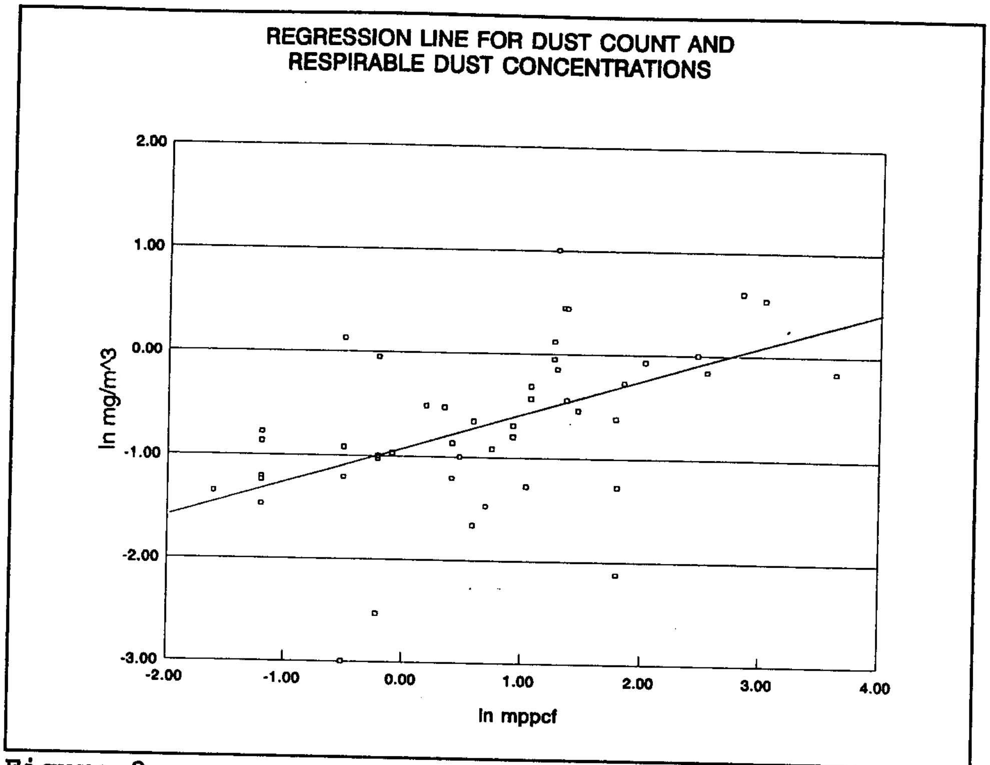

Figure 2

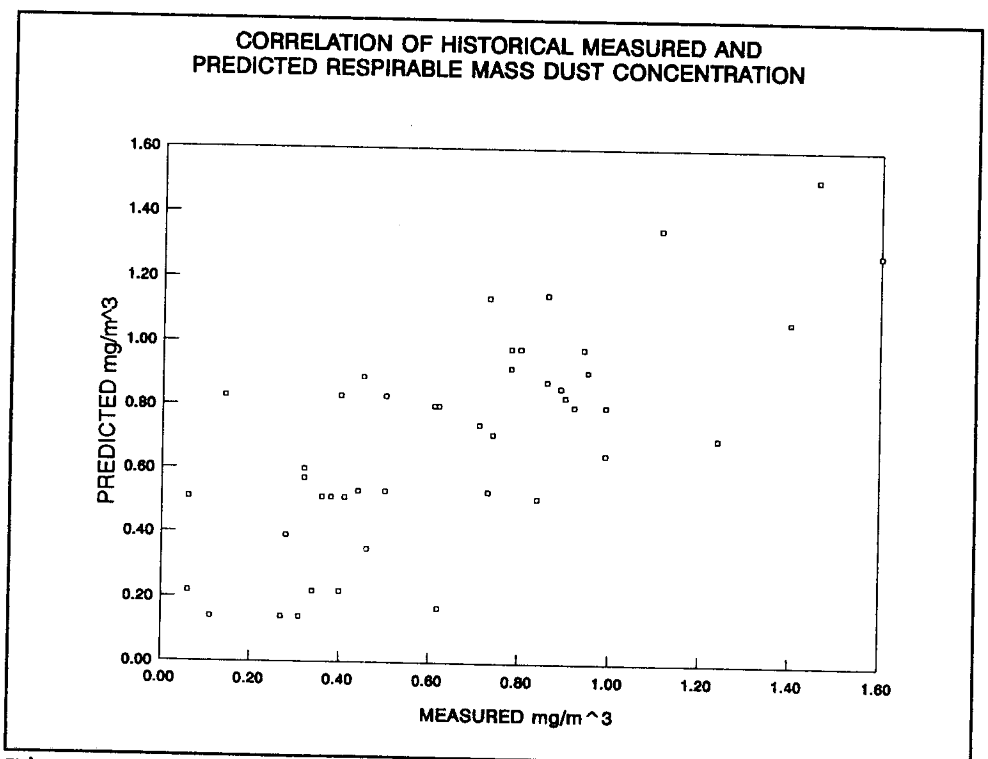

Figure 2

Table I-1

Distribution of samples by year and type

Year	Dust count	Fiber count	Resp dust	Total dust
1952	17	--	--	--
53	1	--	--	--
54	16	--	--	--
55	--	--	--	--
56	2	--	--	--
57	--	--	--	--
58	29	--	--	--
59	8	--	--	--
1960	--	--	--	--
61	7	--	--	--
62	--	--	--	--
63	16	--	--	--
64	15	--	--	--
65	--	--	--	--
66	--	--	--	--
67	--	--	--	--
68	23	--	--	--
69	33	--	--	--
1970	34	21	--	--
71	2	2	--	--
72	9	6	--	--
73	20	66	--	--
74	20	19	--	--
75	50	84	50	23
76	--	82	--	--
77	--	--	4	18
78	--	--	--	58
79	14	14	--	9
1980	16	--	--	16
81	7	--	--	2
82	--	7	4	25
83	23	17	12	32
84	--	--	24	33
85	--	--	18	11
86	59	81	27	14
87	--	22	1	--
88	--	13	25	2
89	7	8	21	14
1990	--	--	20	7
TOTAL	428	442	206	246

Table II-2

Gouverneur Talc work areas and corresponding activities

Work area	Activity	Historical Scores (+/-)	No. of Dust meas.
1. Mill - average	Mill laborer, unspecified	ave. areas 2 - 5	ave. areas 2 - 5
2. Mill - milling	Crusher/dryer operators	+	8
	Wheeler operators	+	7
	Hardinge operators	+	12
	Air process operators	+	0
	Cal process operators	+	0
	Foremen/supervisors/managers	+	2
3. Mill - palletizing/packing	Packers	+	26
	Palletizers	+	
4. Mill - packhouse support	Utility men/pumpmen/laborers	+	9
	Fork lift operators	-	9
	Bulk loaders	-	3
	Foremen/supervisors	-	3
	Car liners	+	2
5. Mill - maintenance	Millwrights	+	9
	Machinists/oilers	+	5
	Electricians	+	3
	Sheet-metal workers/welders	-	3
	Laborer, maint.	-	1
	Instrument repairmen	-	2
6. Mine 1 - Underground	Drillers	+	6
	Driller helpers	-	1
	Slushers/scrapers	+	3
	Trammers	+	4
	Muckers	+	0
	Eimco operators	+	0
	UG crusher operators	+	2
	Pocket cagemen/hoistmen	+	2
	Repairmen	-	1
	Repairman helpers	-	1
	Mechanic	-	1
	Laborer	-	1
	Mine maintenance	-	1
	Blacksmiths/welders	+	0
	Supervisors	+	1
7. Mine 1 - Surface crushing	Surface crusher operators	+	1
8. Mine 2 - Equipment op.	Truck drivers	+	5
	Loader operators	+	4
	Drillers	+	2
	Tractor operators	+	0
9. Mine 2 - Crushing	Crusher operators	+	4
10. Mine 2 - Maintenance	Mobile mechanics	-	1
	Maintenance workers	+	1
	Supervisors	+	1
11. General - minimal exposure	Lab workers	-	0
	Mine managers		
	Construction workers		
	Engineers		
	Janitor		
	Masons		
	Powerline workers		

Table II-2

Work Areas and Activities, cont.

Work Area	Activity	Historical Scores (+/-)	No. of Dust Meas.
11. General - minimal exposure	Quality control Stock clerks Store keepers Surveyors Warehousemen Watchmen	-	0
12. No Exposure	Inventory contr. supervrs. Mine 4 workers Purchasing agents Office clerks & managers Laborers, outside	-	0
99. Unknown		-	0

Table II-3

Effects of work area, year and rater on adjusted exposure scores of 7 raters

Model	Location	Raters	Time period	R^2	P-value		
					Area	Year	Rater
1	Mill	1,2	1948–1953	0.87	0.00	0.01	0.98
2	Mill	1,2,5	1954–1957	0.81	0.00	0.92	1.00
3	Mill	1,2,4,5	1958–1985	0.76	0.00	0.00	1.00
4	Mine 1	1,7	1948–1958	0.96	0.00	0.84	0.96
5	Mine 1	1,7,8	1959–1970	0.69	0.00	0.06	1.00
6	Mine 1	1,3,7,8	1971–1985	0.82	0.00	0.03	1.00
7	Mine 2	1,3,8	1974–1985	0.23	0.00	0.69	1.00

Table II-4

Work area/year-specific exposure scores, rater 1

	Work area										
Year	1	2	3	4	5	6	7	8	9	10	11
1948	8.5	7.8	10	9.5	6.7	4.4	6.0	-	-	-	4.0
1949	8.5	7.8	10	9.5	6.7	4.4	6.0	-	-	-	4.0
1950	8.5	7.8	10	9.5	6.7	4.4	6.0	-	-	-	4.0
1951	8.5	7.8	10	9.5	6.7	4.4	6.0	-	-	-	4.0
1952	7.2	7.2	8.0	7.5	6.0	4.4	6.0	-	-	-	4.0
1953	7.1	7.0	8.0	7.5	6.0	4.4	6.0	-	-	-	4.0
1954	7.1	7.0	8.0	7.5	6.0	4.4	6.0	-	-	-	4.0
1955	6.8	6.5	8.0	7.5	5.3	4.4	6.0	-	-	-	4.0
1956	6.8	6.5	8.0	7.3	5.3	4.5	6.0	-	-	-	4.0
1957	6.8	6.5	8.0	7.3	5.3	4.5	6.0	-	-	-	4.0
1958	6.8	6.5	8.0	7.3	5.3	4.5	6.0	-	-	-	2.5
1959	6.7	6.0	8.0	7.3	5.3	4.5	6.0	-	-	-	2.5
1960	6.2	5.2	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1961	6.1	4.8	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1962	6.1	4.8	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1963	6.1	4.8	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1964	6.1	4.8	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1965	6.1	4.8	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1966	6.1	4.7	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1967	6.0	4.3	8.0	7.3	4.3	4.5	6.0	-	-	-	2.5
1968	5.1	4.3	6.0	5.7	4.3	3.9	3.0	-	-	-	2.5
1969	4.5	4.3	6.0	4.0	3.7	3.9	3.0	-	-	-	2.0
1970	4.6	4.8	6.0	4.0	3.7	3.9	3.0	-	-	-	2.0
1971	4.6	4.8	6.0	4.0	3.7	3.9	3.0	-	-	-	2.0
1972	4.3	3.8	6.0	4.0	3.3	3.4	3.0	-	-	-	2.0
1973	4.2	3.4	6.0	4.0	3.3	3.4	3.0	-	-	-	2.0
1974	4.2	3.4	6.0	4.0	3.3	3.4	3.0	2.3	4.0	1.5	2.0
1975	4.1	3.2	6.0	4.0	3.3	3.4	3.0	2.3	4.0	1.5	2.0
1976	4.1	3.2	6.0	4.0	3.3	3.3	3.0	2.3	4.0	1.5	2.0
1977	4.1	3.2	6.0	4.0	3.3	3.3	3.0	2.3	4.0	1.5	2.0
1978	3.6	2.8	6.0	2.3	3.3	3.3	3.0	2.0	4.0	1.5	2.0
1979	3.1	2.8	4.0	2.3	3.3	3.3	3.0	2.0	4.0	1.5	2.0
1980	3.0	2.8	4.0	2.3	2.7	3.3	2.0	2.0	2.0	1.5	1.5
1981	2.8	2.3	4.0	2.3	2.3	3.3	2.0	2.0	2.0	1.5	1.5
1982	2.8	2.3	4.0	2.3	2.3	3.3	2.0	1.5	2.0	1.5	1.5
1983	2.8	2.3	4.0	2.3	2.3	3.4	2.0	1.5	2.0	1.5	1.5
1984	2.8	2.3	4.0	2.3	2.3	3.4	2.0	1.5	2.0	1.5	1.5
1985	2.8	2.3	4.0	2.3	2.3	3.4	2.0	1.5	2.0	1.5	1.5
1986	2.8	2.3	4.0	2.3	2.3	3.4	2.0	1.5	2.0	1.5	1.5
1987	2.8	2.3	4.0	2.3	2.3	3.4	2.0	1.5	2.0	1.5	1.5
1988	2.8	2.3	4.0	2.3	2.3	3.4	2.0	1.5	2.0	1.5	1.5
1989	2.8	2.3	4.0	2.3	2.3	3.4	2.0	1.5	2.0	1.5	1.5

Table II-5

Work area/calendar year-specific exposure scores, 7 raters

	Work area										
Year	1	2	3	4	5	6	7	8	9	10	11
1948	7.8	6.9	10	8.4	5.7	4.0	5.2	-	-	-	3.5
1949	7.8	6.9	10	8.4	5.7	4.0	5.2	-	-	-	3.5
1950	7.8	6.9	10	8.4	5.7	4.0	5.2	-	-	-	3.5
1951	7.6	6.7	10	8.4	5.4	4.0	5.2	-	-	-	3.5
1952	6.9	6.6	9.1	6.9	5.1	4.0	5.2	-	-	-	3.5
1953	6.6	6.5	8.2	6.7	5.1	4.1	5.2	-	-	-	3.5
1954	6.6	6.0	8.6	6.4	5.4	4.1	5.2	-	-	-	3.4
1955	6.4	5.8	8.3	6.4	5.2	4.1	5.2	-	-	-	3.4
1956	6.4	5.8	8.3	6.4	5.2	4.3	5.2	-	-	-	3.4
1957	6.5	5.9	8.3	6.4	5.2	4.3	5.2	-	-	-	3.4
1958	6.1	5.6	7.7	6.1	5.1	4.3	5.2	-	-	-	2.4
1959	6.1	5.5	7.7	6.1	5.1	4.0	6.1	-	-	-	2.0
1960	5.9	5.1	7.7	6.1	4.6	4.0	6.1	-	-	-	2.0
1961	5.8	4.7	7.7	6.1	4.5	3.9	6.1	-	-	-	2.0
1962	5.8	4.7	7.7	6.1	4.5	4.0	6.1	-	-	-	2.0
1963	5.7	4.7	7.7	5.8	4.5	4.0	6.1	-	-	-	2.0
1964	5.6	4.7	7.5	5.6	4.4	3.8	6.1	-	-	-	2.0
1965	5.6	4.7	7.5	5.6	4.4	3.8	6.1	-	-	-	2.0
1966	5.5	4.6	7.5	5.5	4.2	3.8	6.1	-	-	-	2.0
1967	5.3	4.4	7.1	5.5	4.0	3.8	6.1	-	-	-	2.0
1968	5.0	4.3	6.4	5.1	4.0	3.7	5.2	-	-	-	1.9
1969	4.6	4.2	5.9	4.4	3.8	3.7	2.2	-	-	-	1.5
1970	4.6	4.3	5.9	4.4	3.6	3.7	2.2	-	-	-	1.5
1971	4.4	4.1	5.9	4.2	3.5	3.8	2.9	-	-	-	1.2
1972	4.4	3.9	5.9	4.2	3.4	3.6	2.9	-	-	-	1.2
1973	4.2	3.5	5.9	4.1	3.3	3.6	2.9	-	-	-	1.2
1974	4.0	3.5	5.5	3.9	3.1	3.6	2.9	2.5	3.8	1.1	1.1
1975	3.9	3.2	5.5	3.9	3.1	3.6	2.9	2.5	3.8	1.1	1.1
1976	3.8	3.2	5.2	3.8	2.9	3.6	2.9	2.5	3.8	1.1	1.0
1977	3.6	3.1	4.8	3.6	2.8	3.6	2.9	2.5	3.8	1.1	1.0
1978	3.3	2.9	4.3	3.1	2.7	3.4	2.0	2.4	3.8	1.1	1.0
1979	3.0	2.8	3.6	3.0	2.6	3.4	2.0	2.4	2.0	1.1	1.0
1980	2.7	2.6	3.3	2.7	2.3	3.4	1.8	2.4	1.4	1.1	0.9
1981	2.6	2.5	3.3	2.7	2.0	3.3	1.8	2.4	1.4	1.1	0.9
1982	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9
1983	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9
1984	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9
1985	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9
1986	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9
1987	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9
1988	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9
1989	2.6	2.5	3.2	2.7	2.0	3.2	1.8	2.0	1.4	1.1	0.9

Table II-6

Gouverneur Talc respirable dust exposures

Date	Location	Work area	Job title	Sample conc (mg/m3)
7/30/91	Mill 1	2	Hardinge Operator	0.06
7/30/91	Mill 1	2	Crusher	0.28
7/30/91	Mill 1	2	Crusher Operator	0.91
7/30/91	Mill 1	2	Wheeler Operator	2.64
7/30/91	Mill 1	2	Hardinge Operator	0.08
7/30/91	Mill 1	2	Hardinge Mills 4-6	0.04
7/30/91	Mill 1	2	Hardinge Mill 3	0.02
7/30/91	Mill 1	2	Hardinge Mills 4-6	1.70
7/30/91	Mill 1	2	Wheeler Mills	0.58
7/31/91	Mill 1	2	Wheeler	0.04
7/31/91	Mill 1	2	Hardinge Mills 4-6	0.93
8/01/91	Mill 1	2	Wheeler	2.67
12/10/91	Mill 1	2	Hardinge Mills	0.17
12/10/91	Mill 1	2	Hardinge Mills 4,5	0.08
12/10/91	Mill 1	2	Crusher	0.38
12/10/91	Mill 1	2	Crusher	0.46
12/10/91	Mill 1	2	Hardinge Mills 4,5	0.30
12/10/91	Mill 1	2	Crusher	0.42
12/10/91	Mill 1	2	Wheeler Operator	1.29
12/10/91	Mill 1	2	Crusher Operator	0.60
12/10/91	Mill 1	2	Hardinge Operator	0.69
12/10/91	Mill 1	2	Hardinge Operator	0.61
12/10/91	Mill 1	2	Hardinge Mills 4,5	0.23
12/10/91	Mill 1	2	Wheeler Mills	0.05
12/10/91	Mill 1	2	Crusher	0.48
12/10/91	Mill 1	2	Crusher	0.37
12/11/91	Mill 1	2	Wheeler Mills	0.26
12/11/91	Mill 1	2	Wheeler Mills	0.05
7/29/91	Mill 1	3	Packer	0.18
7/29/91	Mill 1	3	Packer	0.42
7/29/91	Mill 1	3	Pack Line #1	0.93
7/29/91	Mill 1	3	Packer	0.36
7/29/91	Mill 1	3	Packer	0.25
7/29/91	Mill 1	3	Pack Line #3	0.54
7/29/91	Mill 1	3	Pack Line #2	0.19
7/29/91	Mill 1	3	Pack Line #3	1.00
8/01/91	Mill 1	3	Pack Line #3	0.28
8/01/91	Mill 1	3	Pack Line #2	0.95
12/09/91	Mill 1	3	Pack Line #3	0.23
12/09/91	Mill 1	3	Pack Line #3	0.59
12/09/91	Mill 1	3	Packer	0.45
12/09/91	Mill 1	3	Packer	0.27
12/09/91	Mill 1	3	Packer	1.07
12/09/91	Mill 1	3	Packer	0.50
12/09/91	Mill 1	3	Packer	0.32
12/09/91	Mill 1	3	Pack Line #3	0.36
12/10/91	Mill 1	3	Packer	0.62
12/11/91	Mill 1	3	Pack Line #3	0.30
12/12/91	Mill 1	3	Pack Line #2	0.65
12/12/91	Mill 1	3	Pack Line #2	0.66
12/12/91	Mill 1	3	Pack Line #2	0.67
12/12/91	Mill 1	3	Pack Line #2	0.65

Table II-6

Gouverneur Talc respirable dust exposures, cont.

Date	Location	Work area	Job title	Sample conc (mg/m3)
7/29/91	Mill 1	4	Fork Lift Loading	0.30
7/29/91	Mill 1	4	Packer/Serviceman	0.16
7/29/91	Mill 1	4	Laborer	0.64
7/29/91	Mill 1	4	Utility Man	0.30
7/29/91	Mill 1	4	Utility	0.75
7/30/91	Mill 1	4	Off Loader	0.02
7/31/91	Mill 1	4	Asst. Supervisor	0.11
12/09/91	Mill 1	4	Fork Truck Driver	0.11
12/09/91	Mill 1	4	Fork Truck Operator	0.30
12/09/91	Mill 1	4	Packer Serviceman	0.43
12/10/91	Mill 1	4	Bulk Loader	0.18
12/10/91	Mill 1	4	Car Liner	0.54
12/10/91	Mill 1	4	Utility	0.41
12/11/91	Mill 1	4	Fork Lift Loading	0.29
12/11/91	Mill 1	4	Fork Lift Loading	0.13
12/11/91	Mill 1	4	Fork Lift Loading	0.43
7/31/91	Mill 1	5	Sheet Metal	0.20
7/29/91	Mill 1	5	Laborer	0.25
7/30/91	Mill 1	5	Millwright	0.63
7/30/91	Mill 1	5	Millwright	0.18
7/30/91	Mill 1	5	Electrician	0.05
7/31/91	Mill 1	5	Machinist	0.07
12/11/91	Mill 1	5	Millwright	1.10
12/11/91	Mill 1	5	Oiler	0.27
12/11/91	Mill 1	5	Millwright	0.58
12/11/91	Mill 1	5	Millwright	0.87
12/11/91	Mill 1	5	Millwright	0.54
12/11/91	Mill 1	5	Electrician	0.32
12/11/91	Mill 1	5	Millwright	0.49
12/11/91	Mill 1	5	Electrician	0.28
7/31/91	Mine 1	6	Trammer	0.12
7/31/91	Mine 1	6	Cageman	0.32
7/31/91	Mine 1	6	Maintenance	0.19
7/31/91	Mine 1	6	UG Crusher Op	0.32
7/31/91	Mine 1	6	Slusher/Scraper	0.25
7/31/91	Mine 1	6	Driller	0.2
7/31/91	Mine 1	6	Driller	0.38
7/31/91	Mine 1	6	Crusher	1.83
7/31/91	Mine 1	6	Driller	1.97
7/31/91	Mine 1	6	Driller Helper	1.22
7/31/91	Mine 1	6	Supervisor	0.4
7/31/91	Mine 1	7	Surface Crusher	0.14
8/01/91	Mine 2	8	Dump Truck Driver	0.03
8/01/91	Mine 2	8	Driller	0.12
8/01/91	Mine 2	8	Loader Operator	0.03
8/01/91	Mine 2	8	Production Truck Driver	0.77
8/01/91	Mine 2	8	Loader Operator	0.04
12/12/91	Mine 2	8	Truck Driver	0.03
12/12/91	Mine 2	8	Truck Driver	0.55
12/12/91	Mine 2	8	Production Truck Driver	0.2
12/12/91	Mine 2	8	Driller	0.41

Table II-6

Gouverneur Talc respirable dust exposures, cont.

Date	Location	Work area	Job title	Sample conc (mg/m3)
12/12/91	Mine 2	8	Operator	0.11
12/12/91	Mine 2	8	Front End Loader	0.08
8/01/91	Mine 2	9	Crusher	1.59
8/01/91	Mine 2	9	Crusher Operator	0.57
8/01/91	Mine 2	9	Crusher	0.85
12/12/91	Mine 2	9	Crusher	0.32
8/01/91	Mine 2	10	Supervisor	0.01
8/01/91	Mine 2	10	Maintenance	0.04
12/12/91	Mine 2	10	Mobile Mechanic	0.12

Table II-7

Gouverneur Talc work area baseline exposures

No.	Work area	n	Arithmetic Mean (mg/m^3)	Arithmetic Std.dev.	Geometric Mean (mg/m^3)	Geometric Std.dev.
1	Mill 1 - Average		0.46[1]			
2	Mill 1 - Milling	29	0.51	0.59	0.26	3.62
3	Mill 1 - Palletizing/Packing	26	0.53	0.27	0.46	1.70
4	Mill 1 - Packhouse Support	26	0.35	0.23	0.28	2.18
5	Mill 1 - Maintenance	23	0.45	0.27	0.36	2.18
6	Mine 1 - Underground	24	0.73	0.54	0.54	2.27
7	Mine 1 - Surface Crushing	1	0.14	0.14		
8	Mine 2 - Equipment Op.	11	0.22	0.25	0.11	3.36
9	Mine 2 - Crusher	4	0.83	0.55	0.70	1.96
10	Mine 2 - Maintenance	3	0.06	0.06	0.04	3.47
11	Minimal Exposure		0.09[2]			

[1]Average of work areas 2 through 5.
[2]This concentration represents the 5th percentile of all exposure data used to determine baseline exposures.

Table II-8

Work area/calendar year-specific
estimated average respirable dust concentration (mg/m³)*

	Work area										
Year	1	2	3	4	5	6	7	8	9	10	11
1948	1.4	1.7	1.3	1.4	1.3	0.9	0.4	-	-	-	0.2
1949	1.4	1.7	1.3	1.4	1.3	0.9	0.4	-	-	-	0.2
1950	1.4	1.7	1.3	1.4	1.3	0.9	0.4	-	-	-	0.2
1951	1.4	1.6	1.3	1.4	1.2	0.9	0.4	-	-	-	0.2
1952	1.2	1.6	1.1	1.1	1.2	0.9	0.4	-	-	-	0.2
1953	1.2	1.5	1.1	1.1	1.2	0.9	0.4	-	-	-	0.2
1954	1.2	1.5	1.1	1.1	1.2	0.9	0.4	-	-	-	0.2
1955	1.1	1.4	1.1	1.1	1.0	0.9	0.4	-	-	-	0.2
1956	1.1	1.4	1.1	1.1	1.0	1.0	0.4	-	-	-	0.2
1957	1.1	1.4	1.1	1.1	1.0	1.0	0.4	-	-	-	0.2
1958	1.1	1.4	1.1	1.1	1.0	1.0	0.4	-	-	-	0.2
1959	1.1	1.3	1.1	1.1	1.0	1.0	0.4	-	-	-	0.2
1960	1.0	1.1	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1961	1.0	1.1	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1962	1.0	1.1	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1963	1.0	1.1	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1964	1.0	1.1	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1965	1.0	1.1	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1966	1.0	1.0	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1967	1.0	0.9	1.1	1.1	0.8	1.0	0.4	-	-	-	0.2
1968	0.9	0.9	0.8	0.9	0.8	0.8	0.2	-	-	-	0.2
1969	0.8	0.9	0.8	0.6	0.7	0.8	0.2	-	-	-	0.1
1970	0.8	1.0	0.8	0.6	0.7	0.8	0.2	-	-	-	0.1
1971	0.8	1.0	0.8	0.6	0.7	0.8	0.2	-	-	-	0.1
1972	0.7	0.8	0.8	0.6	0.6	0.7	0.2	-	-	-	0.1
1973	0.7	0.7	0.8	0.6	0.6	0.7	0.2	-	-	-	0.1
1974	0.7	0.7	0.8	0.6	0.6	0.7	0.2	0.3	1.7	0.1	0.1
1975	0.7	0.7	0.8	0.6	0.6	0.7	0.2	0.3	1.7	0.1	0.1
1976	0.7	0.7	0.8	0.6	0.6	0.7	0.2	0.3	1.7	0.1	0.1
1977	0.7	0.7	0.8	0.6	0.6	0.7	0.2	0.3	1.7	0.1	0.1
1978	0.6	0.6	0.8	0.4	0.6	0.7	0.2	0.3	1.7	0.1	0.1
1979	0.5	0.6	0.5	0.4	0.6	0.7	0.2	0.3	1.7	0.1	0.1
1980	0.5	0.6	0.5	0.4	0.5	0.7	0.1	0.3	0.8	0.1	0.1
1981	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.3	0.8	0.1	0.1
1982	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1
1983	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1
1984	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1
1985	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1
1986	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1
1987	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1
1988	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1
1989	0.4	0.5	0.5	0.4	0.5	0.7	0.1	0.2	0.8	0.1	0.1

* Estimates are based on the exposure scores of rater 1.

Table II-9

Measured and predicted respirable dust exposures by year and work area

Historical measured exposures				Predicted exposure (mg/m³)
Year	n	Work area	Average (mg/m³)	
1985	8	2	0.84	0.51
1984	13	2	0.36	0.51
1983	15	2	0.38	0.51
1982	4	2	0.06	0.51
1979	4	2	0.32	0.62
1975	12	2	0.99	0.69
1973	2	2	0.74	0.74
1969	5	2	0.89	0.95
1958	3	2	0.73	1.42
1952	3	2	1.11	1.57
1985	5	3	0.73	0.53
1984	6	3	0.44	0.53
1983	4	3	0.50	0.53
1979	2	3	0.32	0.53
1975	6	3	0.95	0.80
1973	2	3	0.80	0.80
1969	6	3	0.78	0.80
1958	2	3	1.60	0.80
1952	1	3	1.46	1.06
1983	1	4	0.46	0.35
1979	2	4	0.28	0.35
1975	10	4	0.41	0.60
1952	3	4	0.45	1.12
1975	10	5	1.24	0.64
1973	2	5	0.71	1.64
1952	1	5	0.86	1.16
1985	7	6	0.61	0.73
1984	9	6	0.62	0.73
1983	10	6	0.92	0.73
1982	2	6	0.99	0.72
1979	12	6	0.40	0.72
1975	14	6	0.86	0.73
1969	10	6	0.78	0.84
1958	8	6	1.40	0.96
1952	8	6	0.94	0.96
1985	1	7	0.27	0.14
1984	2	7	0.11	0.14
1983	3	7	0.31	0.14
1969	1	7	0.62	0.21
1985	5	8	0.40	0.22
1984	2	8	0.06	0.22
1983	3	8	0.34	0.83
1984	3	9	0.90	0.83
1983	1	9	0.50	0.83
1982	2	9	0.14	0.85

*Measured respirable mass data may be converted from historical particle count data by method outlined under Conversion of Dust Counts.

III. RETROSPECTIVE FOLLOW-UP STUDY

OBJECTIVES

The overall purpose of the study was to evaluate the mortality experience of GTC employees. The investigation was an extension of previous retrospective follow-up studies of these workers. It focused on mortality from lung cancer and from NMRD, although other causes of death also were evaluated.

Particular attention was given to examining lung cancer and NMRD rates as functions of estimated cumulative amount of talc ore dust exposure. The purpose was to clarify whether or not there was a consistent dose-response relationship between talc ore dust exposure (or surrogates of dust exposure level) and lung cancer or NMRD. Such information was considered to be of central importance for determining if previously reported positive associations with these diseases were causal or noncausal.

Smoking and, possibly, nonGTC employment history are important potential confounders of the relation between GTC ore dust exposure and lung cancer or other diseases. However, information on these factors was not considered in the present study. This is because smoking and nonGTC employment data were incomplete or missing in the company personnel and medical records of many subjects and because it was not feasible to obtain such data from noncompany sources for each member of the study cohort within a reasonable time frame.

METHODS

The study included white men or men of unknown race who worked for at least one day at the GTC from 1948 (beginning of operations) through 1989 and who had known birth and employment dates. The follow-up period was January 1, 1948, through December 31, 1989. Few women and black men had worked at the plant (about 5% of the workforce), and they were not, therefore, included in the study. The few men of unknown race were assumed to be white.

Cohort identification

We used three information sources to identify subjects. These were a master data file compiled by Lamm et al. (1) for their previous investigation of GTC employees, plant personnel records and Internal Revenue Service (IRS) 941 forms.

The existing data file served as the starting point for subject identification. This file, which contained most of the available information on workers ever employed from 1948 to 1978, included 722 eligible subjects.

Plant personnel records were used to check the completeness of subject identification provided by the master file, to verify the accuracy of data in the file, to identify men who started working at GTC after 1978 and to obtain information on all subjects who did not have a record in the file. Review of plant records identified an additional 89 cohort members.

IRS 941 forms were used to verify the completeness of cohort identification. These forms have been required by the IRS for wage reporting since 1939. They are submitted by an employer to the IRS on a quarterly or annual basis, and they contain the name and Social Security number (SSN) of each employee on the company payroll. IRS data were available for all but 10 (1%) of the 811 previously identified eligible subjects. For one subject, the quarterly IRS report was not available for the only quarter in which he worked. Seven of the remaining subjects without IRS data apparently worked briefly during a single quarter and were discharged for absenteeism. It is not clear that they received wages. The other two subjects without IRS data were short-term salaried employees or consultants. Further review of the IRS data identified seven eligible subjects who did not have a company record. Thus, the final cohort consisted of a total of 818 white men.

The master file developed for the previous study also served as the primary source of information on each cohort member's name, SSN, gender, birth date, hire date and termination date. For subjects who had a master file record and who had continued to work at GTC after 1978 (the latest year included in the file), we updated their employment data using GTC personnel records. For subjects without a master file record but with a personnel record, we abstracted descriptive and employment information from records and added the new data to the file. For subjects identified solely on the basis of IRS records, we estimated hire and termination dates from the IRS information and obtained birth date during vital status tracing, from division of motor vehicles or credit bureau records.

Development of work histories

Personnel records were the primary source of detailed GTC work history information. We abstracted from the available records certain information on each job held by a subject while working at GTC, including the job title, the work location (underground mine, surface mine, mills, etc.), the date started and the date terminated. The GTC personnel department assisted with clarifying information on job and location assignments. The abstracts were developed into an edited computer file. The work area corresponding to each job was determined as described on page 15 of this report and added to the work history data file. Information on specific jobs held at GTC was not available for 46 subjects (6% of the cohort), including the seven subjects identified solely on the basis of IRS data and an additional 39 subjects whose complete plant personnel records could not be located during data collection. The 46 subjects with no work history had a median duration of employment of only 0.19 year.

Exposure estimation

The cumulative dust exposure of each member of the cohort was calculated by linking the subject's work history with the job-exposure matrix, the development of which was described previously in this report. The exposure estimate was the sum of the products of the time spent (days) in a work area/year by the mean estimated respirable dust concentration (mg/m^3) for that area/year:

$$E = \sum_{i=1}^{n} [C_i \cdot T_i],$$

where C_i is the concentration estimate for the ith work area/year and T_i is the time spent in that work area/year. We developed two cumulative exposure estimates for each subject, one based on the work area/year scores of rater 1, and the other based on the average adjusted scores. The two sets of estimates were similar and yielded similar results in all mortality analyses. Therefore, only data using exposure estimates based on the scores of rater 1 are reported.

Vital status and cause of death determination

Information in the master file, updated with subjects' recent employment information, served as the starting point for vital status determination. There were 159 subjects who were active at GTC as of January 1, 1990, and who were, therefore, classified as alive. GTC provided the death certificates of certain deceased employees. We submitted the names of all other subjects both to the National Death Index (NDI), to identify deaths occurring in 1979 or later, and to Pension Benefit Inc. (PBI) to identify subjects who died before 1979. PBI maintains mortality data from the Social Security Administration death master file and other sources. GTC, NDI and PBI identified a total of 225 subjects who died before 1990 and 16 subjects who died in or after 1990. The latter group was classified as alive as the study end date. To confirm that subjects without a GTC, NDI or PBI death record were, in fact, alive, we conducted individual vital status tracing, using personal contact and credit bureau records. This resulted in the identification of an additional 104 subjects as alive. We submitted the names of the remaining untraced subjects to the NY Division of Motor Vehicles. There were 278 subjects who had a driver's license renewal date in or after 1979 and who did not have a GTC, NDI or PBI death record. These men were considered living. Finally, 10 subjects, who had terminated their GTC employment in or after 1979 and who did not have an NDI, PBI or other death record, were classified as alive. The remaining 26 cohort members were classified as lost to follow-up as of the GTC employment termination date.

Death certificates were obtained from the company, when available, and, otherwise, from the states of death. A trained nosologist assigned to each death certificate a code for the underlying cause of death. The nosologist used the Eighth Revision of the International Classification of Diseases (ICD) and the coding rules in effect at the time of death. For most decedents who died in NY, the state provided cause of death data from its computerized decedent data base, rather than a death certificate. This data base contains information on the underlying and contributing causes of death, coded by NY nosologists using the revision of the ICD in effect at the time of death. All NY ICD codes were converted to Eighth Revision codes for data analysis.

Analysis

We compared the overall and cause-specific mortality rates of the study cohort with the rates of white men in the US and NY general populations. The SMR was used as the measure of association for these comparisons.

The SMR is the ratio of the observed number of deaths among cohort members to the expected number, multiplied by 100. We computed expected numbers of deaths by multiplying the age- and calendar time-specific person-years (PY) of the study cohort by the corresponding US, NY or local population rates. The NYS comparison group consisted of the population of NY, excluding New York City. The local comparison group consisted of the populations of Jefferson, Lewis, St. Lawrence, Franklin, Clinton and Essex counties.

PY accumulation began on the hire date or January 1, 1948, whichever was later. Follow-up ended on January 1, 1990, on the death date or on the loss-to-follow-up date, whichever was earliest. We calculated 95% confidence intervals (CIs) of the SMRs assuming a Poisson distribution for the observed numbers of deaths. The most recent version of a program developed by Monson (2) was used for analyses involving comparisons with the US population, whereas a program developed by Marsh (3) was used for analyses using the NY and the local populations as the comparison group.

We performed detailed analyses for certain subgroups of the cohort and for certain causes of death. The subgroups were specified on the basis of work area, cumulative exposure level, years since hire, period of hire, time period of observation, period of death and combinations of these variables. The causes of death examined in detail included lung cancer and NMRD. Two major subtypes of NMRD were evaluated. One of these comprised pneumonia (ICD codes 480-486). The second category, referred to as "other NMRD," included all remaining respiratory system disease codes. Observed deaths in the latter category were from emphysema (N=4), pneumoconiosis (ICD code 515, N=5), other chronic interstitial lung disease (ICD code 517, N=2) and other diseases of the respiratory system including chronic obstructive pulmonary disease (ICD code 519, N=10). "Other NMRD" was examined separately because this category contains NMRD causes of death which are most likely to be dust-related and because it is consistent with, although probably not identical to, groupings that have been used in previous investigations.

We evaluated mortality patterns by cumulative exposure using a stratified internal analysis. For this analysis, exposure categories were specified as at or above versus below the median or as quartiles of the distribution of PY by cumulative mg/m^3-days. The lowest quartile served as the referent category for analyses of lung cancer rates by cumulative exposure quartile, whereas the two lowest quartiles were combined (because of small numbers) to form the referent category for analyses pertaining to NMRD. A subject's PY were distributed among all quartiles through which he passed during his GTC employment. The rate ratio (RR) for each quartile was computed as the weighted average of age/calendar time-specific RRs within that quartile, with weights corresponding to the age/calendar time distribution of PY in the referent category (4). Thus, RRs for the internal analysis are directly standardized for age and calendar time. The test for trend in the RR with cumulative exposure was a modification of the Mantel extension test (5).

RESULTS

General characteristics of the cohort

Of the overall cohort of 818 men, 159 (19%) were still actively working at the close of the study, and 659 (81%) had terminated or retired (table III-1). Twenty-eight per cent of the cohort was deceased, 69% was presumed living, and 3% had an undetermined vital status. Underlying cause of death information was available from death certificates (N=108) or from the NY decedent file (N=112) for 220 (98%) of the 225 decedents.

The median year of hire was 1960, and the median age at hire was 27 years (table III-2). Many subjects had worked at GTC for a short period of time: 344 (42%) subjects, for <1 year and 521 (64%) subjects, for <5 years. The median duration of employment for the overall cohort was 2.0 years. The median number of years of follow-up was 21 years, and the total number of person-years of follow-up was 18,243.

Mortality patterns of the overall cohort

Compared to US white men, GTC employees experienced a 41% increase in overall mortality, based on a total of 225 observed and 160 expected deaths (SMR=141, 95% CI=123-161) (table III-3). Excesses were present for most specific cause of death categories and were statistically significant for cancer (54 observed/35 expected; SMR=154, 115-200), circulatory disease (95/75; SMR=127, 103-155) and NMRD (28/9.6; SMR=293, 195-423).

The cancer excess was attributable primarily to increased mortality from lung cancer (31/12; SMR=254, 173-361). Smaller, statistically nonsignificant increases in observed over expected numbers were present for digestive cancer (10/8.9; SMR=112, 54-206), larynx cancer (2/0.49; SMR=410, 46-1481) and for lymphopoietic cancer (7/3.5; SMR=197, 79-407). There was a statistically significant deficit (3/9.8; SMR=30, 6-89) of cancers other than those of the digestive, respiratory and lymphopoietic system. Two deaths from mesothelioma of the pleura were reported on decedents' death certificates. One of these was coded by NY nosologists as ICD code 212 ("benign neoplasm of the respiratory system") and the other, as ICD code 162.9 ("malignant neoplasm of bronchus and lung, unspecified"), despite the fact that mesothelioma was indicated on the death certificate.

The increase in mortality from circulatory disease was due entirely to more than expected deaths from ischemic heart disease (74/53; SMR=139, 109-175). The overall increase in NMRD deaths was not limited to either of the subcategories examined (pneumonia and other NMRD). However, the excess was largest and was statistically significant only for the latter category (21/6.2; SMR=339, 210-518), which contains diagnoses such as silicosis, asbestosis, pneumoconiosis and chronic obstructive pulmonary disease. A death certificate was available for nine of the 21 decedents in this category. Five of the certificates listed asbestosis (N=1) or pneumoconiosis (N=4) as the underlying cause of death, two listed emphysema, and two listed chronic obstructive pulmonary disease. Among the remaining 12 decedents, the ICD code was consistent with emphysema for two (ICD=492), with chronic obstructive pulmonary disease for eight (ICD code 519), with pneumoconiosis for one (ICD code 515) and with chronic pulmonary fibrosis for one (ICD code 517).

The choice of comparison group (US, NY or local white male general populations) did not affect the results for cancer or for external causes (table III-4). Local rates of NMRD were higher than the US and the NYS rates, and use of local rates to compute expected numbers resulted in about a 30% reduction in the SMR. However, there still was a twofold increase in the cohort's NMRD mortality rate over the local general population rate. Local rates of ischemic heart disease also were higher than US or NYS rates. In contrast to the situation for NMRD, comparison of the cohort with the local general population indicated that there was no meaningful difference in their rates of ischemic heart disease (69/63; SMR=109, 85-139).

The SMR of subjects employed at the GTC for <1 year was higher than the SMR of subjects employed for 1+ years for all causes of death combined, for all cancer, for digestive cancer, for respiratory cancer, for ischemic heart disease and for external causes (table III-5). Almost all of the ischemic heart disease excess among GTC employees compared to US white men was accounted for by the excess among short-term employees. Statistically significantly increased mortality from respiratory cancer and from NMRD was present both among short-term and among longer-term employees. The increased SMR for NMRD among short-term workers was due primarily to an excess of pneumonia deaths (5/1.3; SMR=397, 128-927), whereas the elevated SMR for NMRD among longer-term workers was due primarily to an excess of NMRD deaths other than pneumonia (17/3.9; SMR=437, 255-700).

Tables III-6-III-10 examine mortality patterns by years since hire and years worked for all causes, all cancer, lung cancer, ischemic heart disease and NMRD other than pneumonia, respectively. The overall cancer excess was concentrated among men with <5 years of employment, and within this duration category the excess increased with increasing years since hire (table III-7).

For lung cancer 22 of the total of 31 deaths occurred among men with <5 years of employment (table III-8). The SMR did not rise with increasing length of employment within any category of years since hire. A statistically significant excess was present only for the group with <5 years of employment and 20+ years since hire (19/5.1; SMR=371, 223-580). Subjects with 5+ years of employment and 20+ years since hire had a smaller, statistically nonsignificant increase in lung cancer (7/3.3; SMR=215, 86-442).

In comparisons of the cohort with the local general population, there were no consistent trends in ischemic heart disease mortality with either duration of employment or with years since hire (table III-9). Only subjects with 20+ years of employment and 35+ years since hire had a notable increase in ischemic heart disease (6/1.7; SMR=357, 131-777).

For all NMRD combined, a more than threefold increase was present in the group with 20+ years since hire (21/6.5; SMR=325, 201–496), but within this group there was no effect of duration of employment. When the analysis was limited to NMRD other than pneumonia (table III-10), again there was little evidence of an effect of duration of employment overall or within years since hire subgroups. Subjects with <5 years of employment had an SMR of 300 (11 observed/3.7 expected deaths); subjects with 5+ years of employment had an SMR of 382 (10 observed/2.6 expected deaths).

Increases in mortality from all causes combined, all cancer, lung cancer and ischemic heart disease were limited entirely to men hired before 1955 (table III-11). For example, the group hired before 1955 had 28 observed and 8.8 expected lung cancer deaths (SMR=317, 211–458), whereas men hired in or after 1955 had only 3 observed compared to 3.4 expected deaths. For all NMRD and for NMRD other than pneumonia, an increase was present for both of the year of hire subgroups but was concentrated, again, in men hired before 1955 (all NMRD: 23/7.2; SMR=319, 202–479). Among subjects hired in 1955+, there were only 5 observed and 2.3 expected NMRD deaths.

<u>Mortality patterns by work area</u>

Table III-12 displays the distribution of subjects by nonmutually exclusive work area category. About 50% of the cohort had worked in the talc mills for a median of 1.5 years, 39% had worked in the underground mine (median, 1.7 years), 9%

had worked in the open pit mine (median, 1.7 years), 23% had worked at some point in areas involving minimal exposure (median, 1.7 years), and 11% had ever worked in areas involving no exposure to talc (median, <1 year). A total of 72 subjects had spent a median of 0.22 year in an unknown area.

As seen in table III-13, the overall excess of lung cancer was concentrated among men employed in the underground mine (18/4.1; SMR=440, 261-695). Lung cancer also was increased among subjects ever employed in unexposed jobs (3/0.97; SMR=309, 62-903). The latter increase was due entirely to an excess among men employed <u>exclusively</u> in unexposed jobs (3/0.69; SMR=433, 87-1264). Mill workers had only a small, statistically nonsignificant increase in lung cancer (7/5.0; SMR=139, 56-287). NMRD mortality, in contrast, was elevated among all work area groups, including mill workers (11/3.4; SMR=321, 160-575), underground miners (10/2.9; SMR=349, 167-643), subjects with minimal exposure (9/3.3; SMR=276, 126-525), subjects who had worked in an unknown area (3/0.84; SMR=359, 72-1048) and subjects classified as ever having worked in unexposed jobs (2/0.89).

Table III-14 shows the distribution of subjects by four mutually exclusive work area categories. Of the overall cohort, 336 men (41%) had worked in the talc mills but not in the mines, 278 (34%) had worked in the mines but not in the mills, 53 (6%) had worked both in the mines and in the mills, and 99 (12%) had worked in neither the mines nor the mills. For 52 (6%) men, we were unable to determine if they had worked in the mines, the mills, both areas or neither area.

Analysis of mortality patterns by mutually exclusive work area confirmed the results observed in the nonmutually exclusive work area analysis. The lung cancer excess was concentrated among subjects employed only in the mines (18/3.8; SMR=473, 280-747), whereas NMRD was increased both in the mill only group (11/3.2; SMR=347, 173-622) and in the mine only group (10/2.6; SMR=380, 182-698) (table III-15). More than expected NMRD deaths were observed among subjects who had never worked in the GTC mines, mills or an unknown area (6 observed/3.0 expected). However, the increase in NMRD deaths in this work area group was due mostly to pneumonia (3 observed/1.1 expected), whereas for other NMRD there was only a slight increase (3 observed/1.9 expected).

Mortality patterns by estimated cumulative exposure

The median estimated cumulative respirable dust exposure was 428 mg/m^3-days for the overall cohort, 730 mg/m^3-days for men ever employed in the underground mine and 686 mg/m^3-days for men ever employed in the mills. Median values were 628 mg/m^3-days for men employed in the mines but not in the mills; 574 mg/m^3 days for men employed in the mills but not in the mines; and 21 mg/m^3-days for men who never worked in the mines, the mills or an unknown area.

For lung cancer there was an inverse relationship with estimated cumulative exposure, with the RR being 0.66 (0.32-1.4) for subjects with cumulative exposure greater than or equal to versus below the median value. Analysis by quartiles also suggested an inverse association (trend p-value, 0.13) (table III-16). When analyses were restricted to men who started work before 1955, these results were unchanged (≥ vs. < median: RR = 0.62, 0.28–1.4). Restriction of the analysis to subjects with ≥1 year of GTC employment yielded an RR of 0.62 (0.22–1.8) for exposure ≥ vs. < the median.

For all NMRD coded as the underlying cause of death, cumulative exposure at or above the median was associated with an RR of 1.9 (0.84–4.3). The dose-response pattern was irregular, with RRs of 1.0, 1.8 and 1.8 for quartiles 1 and 2 combined, quartile 3 and quartile 4 (p-value for trend, 0.13). For NMRD other than pneumonia, the RR was 3.1 (1.1–9.7) for subjects with exposure at or above versus below the median value. There was an irregular dose-response relationship, with RRs of 1.0 for quartiles 1 and 2, 3.6 (1.1–12.6) for quartile 3 and 2.7 (0.84–8.9) for quartile 4 and with a p-value for trend of 0.07. All seven subjects who had pneumoconiosis or interstitial lung disease as their underlying cause of death had cumulative exposure above the cohort's median value (see below). Thus, their RR was infinity.

A total of 21 decedents had diagnoses of NMRD other than pneumonia on their death certificates, but NMRD was not indicated as the underlying cause. Of these, one had an ICD code of 5184, indicating acute pulmonary edema; one had a code of 5180 (pulmonary collapse); and one had a code of 514 (pulmonary congestion). These three cases were not considered further because their NMRD diagnoses differed substantially from those of all other decedents with NMRD recorded as the underlying or as a contributory cause of death. Of the remaining 18 decedents with NMRD coded as a contributory cause, four had pneumoconiosis, talcosis, asbestosis or pulmonary fibrosis; six had emphysema; and eight had chronic obstructive pulmonary disease. Cumulative exposure estimates were available for 15 of the 18 cases. For further internal analyses of other NMRD mortality by cumulative exposure, these 15 decedents were combined with the 20 decedents who had emphysema, chronic obstructive pulmonary disease or pulmonary fibrosis as the underlying cause of death and who had cumulative exposure data.

Based on the total series of 35 cases of NMRD other than pneumonia, the RR was 2.2 (1.0–4.8) for cumulative exposure at or above versus below the median value (table III-16). The dose-response pattern, again, was irregular. The RR for pneumoconiosis and related conditions, based on a total of 11 cases, was 3.7 (0.8–17.6) for cumulative exposure at or above (9 cases) versus below (2 cases) the median value.

Other information on decedents with respiratory cancer and NMRD

Table III-17 provides additional information on decedents with respiratory cancer. Subjects with lung cancer had a median age at death of 62 years, a median hire year of 1949, a median age at hire of 33 years, a median duration of employment at GTC of 0.86 year and a median length of time from first hire to death of 32 years. Their median estimated cumulative dust exposure was 297 mg/m^3-days, 31% lower than in the overall cohort. GTC job histories were unavailable for two lung cancer decedents, both of whom worked for less than one year. No decedent had lung cancer identified as a contributory, but not underlying, cause of death.

Both of the two subjects with larynx cancer were short-term employees. One (no. 414) worked at the GTC for only one day. His pre-GTC employment history is unknown. The other (no.806) had worked in lead mining and for another talc company.

Of the two men with mesothelioma, one (no. 351) worked at the GTC for 15 years and had relatively high cumulative exposure. However, only about 15 years had elapsed between this subject's hire and death dates, a time period that may have been inadequate for the induction of his mesothelioma. He began working at the GTC at 46 years of age, and his previous employment included about 16 years as a carpenter and millwright, 8 years as a lead miner and 5 years as a repairman in a milk plant. The other decedent (no. 675) worked only briefly at the GTC and was identified solely on the basis of IRS records. An interview with his next-of-kin indicated that he had worked at GTC as a draftsman during mill construction in 1948-1949 and that his work was outdoors, a history which implies that he would have had minimal exposure to GTC talc dust. This interview, as well as information from his medical records, also indicated that he had worked for several years on the construction of another talc mine in the same geographical area before his GTC employment. After completing his GTC employment, the subject operated a fuel oil company that removed, installed, maintained and repaired oil burner heating systems and that delivered fuel oil to commercial and residential establishments. Although the subject's medical records reported that he had no history of exposure to asbestos, it remains possible that he was exposed sporadically to asbestos in insulating materials used in his fuel oil business.

Table III-18 provides similar information on decedents with NMRD recorded as the underlying cause of death. The seven decedents with pneumonia had median values of 62 years for age at death, 1949 for hire year, 41 years for age at hire, 0.39 for years worked, 21 for years since first hire and 134 mg/m^3-days for cumulative dust exposure. Three of the seven decedents had worked in mining jobs before coming to the GTC. The 21 decedents with NMRD other than pneumonia had median values of 64 years for age at death, 1950 for hire year, 36 years for age at hire, 3.0 for years worked and 31 for years since first hire. Their median cumulative dust exposure was 1202 mg/m^3-days, almost three times as high as that of the overall cohort. The seven men who had pneumoconiosis or interstitial lung disease as the underlying cause of death had median values of 64 years of age at death, 1953 for hire year, 37 years for age at hire, 14 for years worked and 21 for years since hire. Their median cumulative dust exposure was 5806 mg/m^3-days, more than 13 times higher than that of the overall cohort. Seventeen of the 21 men with other NMRD, including six of the seven men with pneumoconiosis or interstitial lung disease, had done mining or quarrying work before starting employment at the GTC. Of the three other NMRD decedents with only minimal exposure to GTC ore dust, one had previously worked as a vehicle mechanic, one had worked in mine shaft construction, and one had been a milk plant manager before beginning work at the GTC.

Table III-19 displays data on the 18 decedents with NMRD, other than pneumonia or pulmonary edema, collapse or congestion, recorded as a contributory, but not underlying, cause of death. These men had median values of 64 years of age at death, 1940 for hire year, 35 years for age at hire, 1.1 for years worked and 33 for years since hire. Their median cumulative dust exposure was 628 mg/m^3-days. Fourteen had worked in mines.

When decedents with other NMRD as the underlying cause of death were combined with decedents having other NMRD as a contributory cause, the total series of 39 decedents had median values of 64 years of age at death, 1950 for hire year, 36 years for age at hire, 2.3 for years worked and 31 for years since hire. Their median cumulative dust exposure was 892 mg/m^3-days, about twice that of the overall cohort.

DISCUSSION

The present study has several advantages compared to the investigations of GTC employees done by NIOSH (6,8,9) and by other researchers (1,7). First, it is larger and, therefore, more informative than the previous research. Compared to the NIOSH study, it increases the follow-up period by seven years and includes 15% more subjects, 19% more PY and 40% more deaths.

Second, the present study evaluates mortality patterns by work area and by estimated cumulative exposure, factors that were not considered in previous investigations. Such evaluations, particularly the assessments of dose-response, are helpful in determining whether observed associations are causal or noncausal.

Third, the present study includes comparisons of the cohort's mortality rates with regional and local, in addition to US, general population rates, and the analyses of mortality rates by cumulative exposure used an internal referent group. These features should reduce the possibility that observed results are due to confounding or to observation bias.

The study has several limitations. Detailed work histories were not available for 6% of the cohort, and subjects with missing work histories were not included in analyses of mortality patterns by work area or cumulative exposure. The effect of these exclusions is difficult to assess. Thirty-four of the 46 men with missing work histories had worked at the GTC for less than one year and would have had relatively low cumulative exposure, even if they had worked in high exposure areas such as the underground mine or the mill packhouse. The group of 34 short-duration employees includes the two lung cancer decedents with missing work histories, both of whom would have had cumulative exposure, at most, in the second quartile. The one other NMRD decedent with a missing work history was a very short-term employee who could only have had low exposure.

Misclassification of subjects by cumulative exposure is a source of error inherent in the exposure estimation process used for this study. However, because we developed the work area/job/time period exposure estimates and linked these estimates with subjects' work histories using procedures that did not involve any reference to disease outcome, misclassification errors should be nondifferential. The usual effects of nondifferential misclassification are to reduce the strength of associations and to obscure dose-response relationships. These effects are relevant primarily to the interpretation of our results pertaining to lung cancer and NMRD trends by estimated cumulative exposure, as discussed later. The use of an improper or biologically irrelevant exposure index is also a potential weakness. We did not estimate subjects' peak exposure intensities, nor did we attempt to measure exposure to respirable fibers.

Another limitation of the present investigation is the lack of information on two important potential confounders of the association between talc dust exposure and lung cancer and NMRD.

Cigarette smoking is a recognized and potent cause of lung cancer and of certain types of NMRD. Because we did not have data on the smoking habits of the cohort we cannot rule out the possibility that the patterns we observed are due in part to smoking differences among subjects in various cumulative exposure categories or between the cohort and the general population. Occupational exposure to lung carcinogens and to other respiratory system hazards in jobs other than at the GTC is another potential confounder. The fact that many cohort members worked at GTC for a short period of time (median, 2.0 years) indicates that a substantial proportion of subjects spent most of their working lifetimes in jobs other than at the GTC. Information on lung cancer and NMRD decedents' employment before starting at the GTC indicated that many of them worked in talc or other types of mining before coming to the GTC, and some held other potentially high-risk jobs such as construction worker and auto mechanic. We had no information on post-GTC employment, which for most subjects would account for a longer period of time than their work before or during GTC employment.

Further limitation that should be mentioned is the lack of medical records and detailed death certificate information on NMRD and ischemic heart disease decedents. There may be considerable misclassification of decedents with respect to types of NMRD that could be related to dust exposure. This misclassification is due to difficulties with the clinical diagnosis of various respiratory diseases and possible overlap between NMRD and cardiovascular disease. In addition, NMRD may be present at death, yet may not be mentioned on the death certificate. If the tendency to list NMRD as a cause was greater for talc worker decedents than for other decedents in the general population, observation bias away from the null would occur, resulting in NMRD SMRs that are too high. Also, if the tendency to list NMRD as a cause increases with increasing exposure, dose-response patterns could be distorted.

Most of the mortality patterns seen in the present study for the overall cohort are similar to patterns reported previously for GTC workers (1,6-9). GTC employees, compared to general populations, experienced increased mortality rates for most diseases, particularly for lung cancer and NMRD. Most of the excesses tended to be higher in, but were not limited to, short-term employees.

Our study found that men hired in 1955 or later had mortality rates for disease categories other than NMRD, including all causes, all cancer and lung cancer, that were similar to comparison population rates. These results could be interpreted as indicating that any GTC occupational exposure related to lung cancer or to conditions other than NMRD was removed or was controlled effectively by the late 1950s. However, data on subjects who started working at the GTC in or after 1955 were too imprecise to exclude the possibility of a small excess of deaths from all causes combined or of a moderate lung cancer excess in this group. In addition, subjects hired in or after 1955 have had a shorter period of time for the expression of exposure-related diseases with long induction times. Thus, more follow-up will be required to determine if GTC employees hired after the mid-1950s are free of excess disease.

The lung cancer excess in the overall cohort was moderately strong and was concentrated among men with 20 or more years since hire. Although these two features suggest that some aspect of employment at the GTC causes lung cancer, several other observations detract from such an interpretation.

Gamble, in a nested case-control study 22 of the 31 lung cancer decedents identified in the present investigation, reported that all of the lung cancer cases and that 73% of controls selected from among other members of the GTC cohort had been smokers (9). These smoking prevalences are rather high. However, although some of the lung cancer excess among GTC employees probably is due to confounding by cigarette smoking, it is unlikely that the entire increase is attributable to this factor.

Several features of the data argue more strongly against a causal interpretation. Although there was a greater than fourfold increase among men who worked in the underground mine, a high exposure area, there was a similar increase among GTC employees classified as unexposed to talc. This indicates that some of the overall increase in the cohort is due to confounding.

Moreover, there was little evidence of an increase among mill workers, a group with exposures similar to those of underground miners. This pattern suggests that the increase in underground miners is not due to talc dust exposure.

More importantly, the lung cancer decedents appear to have had low exposure when compared to other GTC workers. Their median duration of employment (0.86 year) was lower than that of the overall cohort (2.0 years) and was about the same as that of subjects hired before 1955 (0.90 year). They had a median estimated cumulative exposure (297 mg/m^3–days) lower than that of the overall cohort (428 mg/m^3–days) or of subjects hired before 1955 (366 mg/m^3–days).

Internal analysis of lung cancer rates by cumulative exposure indicated a null or inverse relationship. Such a pattern is inconsistent with the hypothesis that GTC talc ore, per se, is a lung carcinogen. These results also do not support a conclusion that the lung cancer excess at the GTC is attributable to exposure to mineral contaminants having carcinogenic potential similar to that of asbestos, as studies of workers exposed to asbestos have demonstrated moderate to strong positive dose–response relationships (10). Our findings could only be consistent with such an interpretation if contaminant levels were uncorrelated or inversely correlated with our measure of cumulative respirable dust.

NMRD mortality patterns differed from those seen for lung cancer in several respects. NMRD was elevated both among subjects hired before 1955 and among subjects hired in 1955 or later, although the increase in the latter group was based on small numbers. There also was a statistically significant threefold increase in NMRD among both mine workers and mill workers. NMRD decedents had high median exposure relative to the overall cohort (884 mg/m^3-days vs. 428 mg/m^3-days). Although the total group of NMRD decedents had a lower median duration of employment at GTC than all subjects combined, the subgroup of decedents with NMRD other than pneumonia (i.e., the category of NMRD most likely to contain dust-related disease) had worked slightly longer at the facility than the overall cohort. Decedents with pneumoconiosis or interstitial lung disease had median values for duration of employment and cumulative dust exposure that were seven and 13 times higher, respectively, than the corresponding values of the overall cohort. Internal comparisons suggested a positive relationship between estimated cumulative dust levels and NMRD mortality, particularly for NMRD other than pneumonia.

As with lung cancer, differences between GTC workers and the general population with respect to smoking and nonGTC occupational exposures probably explain some of the overall excess of NMRD seen in the external comparisons made in this study. The observations of elevated SMRs among short-term workers is consistent with this interpretation. Also, the observations that NMRD decedents had a median age at hire of nearly 40 years and that many of them had worked in other mining operations before coming to the GTC suggest that exposures sustained in nonGTC jobs contributed to the development of respiratory disease among some of the NMRD decedents in this study. However, the impact of potential confounding by smoking and nonGTC occupational exposures should have been reduced in the internal analyses.

Similarly, the potential for observation bias due to selective reporting of NMRD on the death certificates of deceased talc workers should have been lower in the internal analyses than in the external analyses. However, even in the internal analyses, any tendency for the reporting of NMRD as a cause of death to increase with increasing amounts of cumulative exposure would produce bias. The internal analyses using all cases of emphysema, pneumoconiosis and related conditions and chronic obstructive pulmonary disease found slightly lower RRs for cumulative exposure than did the analyses based on cases of NMRD indicated as the underlying cause of death. This suggests that the positive association indicated by the latter results were due in part to observation bias. Nonetheless, a moderate association between NMRD and estimated exposure persisted in all analyses.

On balance, the positive associations seen in these analyses support the notion of a causal relationship between exposure to GTC talc ore dust and NMRD. The lack of an internally consistent, strong dose-response trend may reflect random misclassification of subjects by cumulative exposure, as well as our inability to identify a pathologically and clinically homogeneous category of NMRD.

The cohort had a small increase in deaths from lymphopoietic cancer. This increase was based on only 7 observed and 3.5 expected deaths and was not limited to any particular subtype of lymphopoietic cancer. It is probably due to chance or to confounding by an unidentified factor, such as a non-GTC occupational exposure.

Comparisons of GTC workers with the US general population indicated an excess of ischemic heart disease. However, this was reduced substantially in comparisons with the local general population. Ischemic heart disease rates were not associated consistently with duration of employment or with time since hire. Although a statistically significant increase was observed in the subgroup of subjects having 20 or more years of employment and 35 or more years since hire, compared to the local population, this result was based on small numbers and had a lower bound of the CI that was close to the null value.

In summary, the reason for the association between employment at GTC and lung cancer remains unclear. It may be due in part to confounding by smoking and by other unmeasured risk factors and in part to chance. It is unlikely to be related to respirable talc ore dust from the GTC mines and mills, per se. However, an unidentified constituent of the ore or of the underground mine environment (e.g., radon), exposure to which is poorly correlated with total respirable dust exposure, may be responsible for some of the excess lung cancer. We have no information, apart from the disease patterns seen in this study, to substantiate or refute this speculation. Radon measurements are not available for the early time period of GTC underground mine operations. The cohort has an increased rate of NMRD that is probably related to exposure to GTC talc ore dust, to dust exposures encountered in nonGTC jobs and to smoking. Patterns of other causes of death among GTC workers are unremarkable.

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Table III-1

Number of subjects by employment status and vital status as of January 1, 1990

	No.	%
Total	818	100
Employment status:		
Active	159	19
Inactive	659	81
Vital status:		
Presumed living	567	69
Deceased	225	28
With death certificate data	(220)	(98)
Without death certificate data	(5)	(2)
Unknown	26	3

Table III-2

Number of subjects by age at hire, year of hire, years worked and years of follow-up

	No.	%
Age at hire (yrs):		
<20	113	14
20-24	200	24
25-29	162	20
30-34	140	17
35+	203	25
Median = 27		
Year of hire:		
<1950	186	23
1950-1954	155	19
1955-1959	68	8
1960-1964	43	5
1965-1969	81	10
1970-1974	165	20
1975+	120	15
Median = 1960		
Years worked:		
<1	344	42
1-4	177	22
5-9	74	9
10-14	61	7
15+	162	20
Median = 2.0		
Years of follow-up:		
<10	139	17
10-19	242	29
20-29	177	22
30+	260	32
Median = 21		

Table III-3

Observed/expected numbers of deaths and SMRs by cause of death

	Observed/Expected	SMR	95% CI
All causes	225/160	141	123–161
All cancer	54/35	154	115–200
Digestive system	10/8.9	112	54–206
Respiratory system	34/13	266	184–371
Larynx	2/0.49	410	46–1481
Lung	31/12	254	173–361
Lymphopoietic system	7/3.5	197	79–407
Other cancer	3/9.8	30	6–89
Circulatory disease	95/75	127	103–155
Ischemic heart disease	74/53	139	109–175
Other circulatory disease	21/22	97	60–148
NMRD*	28/9.6	293	195–423
Pneumonia	7/3.3	214	86–441
Other NMRD	21/6.2	339	210–518
Digestive disease	12/7.6	157	81–274
External causes	21/19	110	68–168
Accidents	17/12	136	79–217
Motor vehicle	8/6.3	127	55–251
Other	9/6.2	144	66–274
Other external causes	4/6.6	61	17–156
Residual known causes	10/13	75	36–139
Unknown	5		

*Non-malignant respiratory disease.

Table III-4

Observed numbers of deaths and expected numbers*, calculated using mortality rates of the white male general population of the United States, New York State (NYS) not including New York City, or the local six-county area (local)

		Expected		
	Observed	U.S.	NYS	Local
All causes	209	145	140	160
All cancer	54	35	36	37
Digestive system	10	8.9	10	9.8
Respiratory system	34	13	13	14
Lung	31	12	12	13
Lymphopoietic system	7	3.5	3.8	3.6
Ischemic heart disease	69	49	55	63
NMRD	28	9.0	8.5	13
External causes	16	16	11	15

*The follow-up period is 1960–1989 for all causes and for all noncancer categories and 1950–1989 for cancer.

Table III-5

Observed/expected numbers of deaths and SMRs
by cause of death and years worked (<1 year or 1+ years)

	Worked <1 year (PY=8,609)			Worked 1+ years (PY=9,634)		
	Obs/Exp	SMR	95% CI	Obs/Exp	SMR	95% CI
All causes	105/65	160	131–194	120/94	127	106–152
All cancer	27/14	192	126–279	27/21	128	84–187
Digestive system	5/3.6	139	45–325	5/5.3	93	30–218
Respiratory system	18/5.1	355	210–561	16/7.7	207	118–336
Lung	17/4.8	352	205–564	14/7.4	190	104–319
Lymphopoietic system	2/1.5	136	15–490	5/2.1	241	78–563
Circulatory disease	47/30	157	115–208	48/45	107	79–142
Ischemic heart disease	37/21	175	123–241	37/32	115	81–159
Other circulatory disease	10/8.8	113	54–208	11/13	85	43–153
NMRD	9/3.7	246	112–466	19/5.9	322	194–503
Other NMRD*	4/2.4	167	45–427	17/3.9	437	255–700
Digestive disease	5/3.2	156	50–365	7/4.5	157	63–324
External causes	13/9.0	144	77–246	8/10	80	34–157
Accidents	11/6.0	182	91–325	6/6.5	93	34–201
Motor vehicle	7/3.1	223	89–459	1/3.1	32	1–177
Other	4/2.9	137	37–352	5/3.3	150	49–350
Unknown	3			2		

*NMRD other than pneumonia

Table III-6

Observed/expected numbers of deaths from all causes and SMRs by years since hire and years worked

Years since hire	Years worked	Observed/ expected	SMR	95% CI
<5	<5	12/14	88	45-151
	5-19	-	-	-
	20+	-	-	-
5-19	<5	50/32	158	117-208
	5-19	27/23	115	76-168
	20+	-	-	-
20-34	<5	68/41	166	129-210
	5-19	17/14	120	70-192
	20+	21/15	139	86-213
35+	<5	18/12	155	92-245
	5-19	1/4.7	21	1-118
	20+	11/4.0	272	136-487

Table III-7

Observed/expected numbers of cancer deaths and SMRs by years since hire and years worked

Years since hire	Years worked	Observed/ expected	SMR	95% CI
<5	<5	0/2.0	0	0–182
	5+	–	–	–
5–19	<5	10/5.9	170	82–313
	5+	5/4.7	107	35–249
20+	<5	29/13	215	144–309
	5+	10/9.1	110	53–203

Table III-8

Observed/expected numbers of lung cancer deaths and SMRs by years since hire and years worked

Years since hire	Years worked	Observed/ expected	SMR	95% CI
<5	<5	0/0.48	0	0–769
	5+	–	–	–
5–19	<5	3/1.8	167	34–487
	5+	2/1.5	130	16–469
20+	<5	19/5.1	371	223–580
	5+	7/3.3	215	86–442

Table III-9

Observed/expected* numbers of ischemic heart disease deaths and SMRs by years since hire and years worked

Years since hire	Years worked	Observed/ expected	SMR	95% CI
<5	<5	1/1.9	54	1-304
	5-19	-	-	-
	20+	-	-	-
5-19	<5	10/11	89	43-164
	5-19	9/8.9	101	46-191
	20+	-	-	-
20-34	<5	23/19	123	78-184
	5-19	4/6.5	61	17-157
	20+	9/6.9	130	59-246
35+	<5	7/4.9	142	57-292
	5-19	0/2.1	0	0-179
	20+	6/1.7	357	131-777

* Expected numbers based on local, six-county rates.

Table III-10

Observed/expected numbers of other NMRD* deaths and SMRs by years since hire and years worked

Years since hire	Years worked	Observed/ expected	SMR	95% CI
<5	<5	0/0.28	0	0-1318
	5+	-	-	-
5-19	<5	3/0.91	330	68-964
	5+	2/0.71	282	34-1017
20+	<5	8/2.5	323	139-635
	5+	8/1.9	419	181-825

*NMRD other than pneumonia.

Table III-11

Observed/expected numbers of deaths and SMRs for selected causes by year of hire*

	Year of hire	Observed/ expected§	SMR	95% CI
All causes	<1955	184/115	161	138-186
	1955+	41/45	91	65-123
All cancer	<1955	46/25	181	132-241
	1955+	8/9.7	83	36-163
Lung cancer	<1955	28/8.8	317	211-458
	1955+	3/3.4	90	18-262
Ischemic heart disease	<1955	56/46	122	92-158
	1955+	13/17	77	41-132
All NMRD	<1955	23/7.2	319	202-479
	1955+	5/2.3	214	69-499
Other NMRD+	<1955	18/4.8	379	225-599
	1955+	3/1.5	196	40-454

* Median values of years worked and years since hire by time period of hire: hired <1955, 0.90 and 35; hired in 1955+, 3.2 and 16.

§ Expected numbers are based on US rates, except for ischemic heart disease. Ischemic heart disease expected numbers are based on local, six-county rates.

+ NMRD other than pneumonia.

Table III-12

Number of subjects, median years worked and median start year by non-mutually exclusive work area

Area*	Subjects	Median years worked		Median start year	
		At GTC	In area	At GTC	In area
Talc mills	389	3.0	1.5	1962	1963
Labor, unspecified	258	2.6	0.34	1968	1969
Milling	165	7.5	1.9	1969	1972
Packing	66	15	1.8	1974	1974
Packhouse support	88	14	1.2	1959	1969
Maintenance	118	7.7	2.5	1955	1960
Underground mine	319	3.4	1.7	1960	1962
Underground operations	318	3.4	1.5	1960	1962
Surface crushing	17	9.2	1.1	1974	1978
Open pit mine	71	12	1.7	1974	1978
Equipment operating	59	12	1.6	1974	1977
Crushing	17	12	0.21	1974	1984
Maintenance	14	16	2.0	1974	1984
Minimal exposure (mills, mines, other)	185	5.6	1.7	1964	1968
No exposure	89	8.5	0.78	1974	1978
Unknown area	72	0.34	0.22	1952	1952

* The work area categories are not mutually exclusive. A subject is counted in each area where he worked.

Table III-13

Observed/expected numbers and SMRs for selected causes of death by nonmutually exclusive work area

Area*		All causes	Cancer	Lung cancer	NMRD
Talc mills, overall	Obs/Exp	85/63	21/14	7/5.0	11/3.4
	SMR	136	149	139	321
	95% CI	108–168	92–228	56–287	160–575
Underground mine, (UGM), overall	Obs/Exp	96/52	26/11	18/4.1	10/2.9
	SMR	186	226	440	349
	95% CI	151–227	148–332	261–695	167–643
Open pit mine, overall	Obs/Exp	4/3.28	0/0.78†	0/0.29	0/0.14
	SMR	122	–	–	–
	95% CI	33–312	–	–	–
Minimal exposure	Obs/Exp	42/47	8/10	3/3.4	9/3.3
	SMR	90	78	88	276
	95% CI	65–121	34–154	18–256	126–525
No exposure	Obs/Exp	15/14	4/3.0	3/0.97	2/0.89
	SMR	104	132	309	–
	95% CI	58–172	36–338	62–903	–
Unknown area	Obs/Exp	26/15	5/3.4	2/1.2	3/0.84
	SMR	174	149	–	359
	95% CI	114–256	48–347	–	72–1048

* The categories are not mutually exclusive.
† SMR and CI are not computed when both the observed and the expected number are less than 2.

Table III-14

Number of subjects, median years worked, median start year and percent ever hourly by mutually exclusive work area

Area	Subjects	Median years worked		Median start year		% ever hourly
		At GTC	In area	At GTC	In area	
Mills ever, mines never	336	2.3	1.5	1959	1959	97
Mines ever, mills never	278	3.1	2.0	1956	1956	97
In both mills and mines	53	7.6	7.1	1974	1974	100
Never in mills, mines or an unknown area	99	1.7	1.7	1965	1965	61
Unknown if ever in mills or mines	52	0.24	0.24	1952	1952	79

Table III-15

Observed/expected numbers and SMRs for selected causes of death by mutually exclusive work areas

		All causes	Cancer	Lung cancer	NMRD
Mills ever, mines never	Obs/Exp	81/58	20/13	7/4.7	11/3.2
	SMR	141	153	150	347
	95% CS	112-175	94-237	60-308	173-622
Mines ever, mills never	Obs/Exp	93/47	25/11	18/3.8	10/2.6
	SMR	197	236	473	380
	95% CS	159-241	152-348	280-747	182-698
In both mills and mines	Obs/Exp	4/5.2	1/1.1	0/0.34	0/0.26
	SMR	76	–	–	–
	95% CI	21-195	–	–	–
Never in mills, mines, or an unknown area	Obs/Exp	32/40	5/8.2	4/2.6	6/3.0
	SMR	81	61	155	202
	95% CI	55-114	20-142	42-398	74-440
Unknown if ever worked in mills or mines	Obs/Exp	15/9.7	3/2.2	2/0.77	1/0.52
	SMR	155	138	–	–
	95% CI	87-255	28-403	–	–

Table III-16

Age- and calender year-adjusted rate ratios (RRs)*
for lung cancer, all nonmalignant respiratory disease (NMRD)
and NMRD other than pneumonia ("other NMRD")

Cumulative exposure (mg/m^3-days)	Deaths	Person-years	RR	95% CI
Lung Cancer				
0 - 62	10	4,274	1.0+	-
63 - 325	6	4,175	0.74	0.27 - 2.1
326 - 1,704	6	4,266	0.68	0.24 - 1.9
1,705+	7	4,236	0.45	0.17 - 1.2
		Trend p-value = 0.13		
All NMRD (underlying cause of death)				
0 - 325	9	8,449	1.0+	-
326 - 1,704	8	4,266	1.8	0.69 - 4.5
1,705+	10	4,236	1.8	0.72 - 4.5
		Trend p-value = 0.13		
Other NMRD (underlying cause of death)				
0 - 325	4	8,449	1.0+	-
326 - 1,704	7	4,266	3.6	1.1 - 13
1,705+	9	4,236	2.7	0.84 - 8.9
		Trend p-value = 0.07		
Other NMRD (underlying or contributory cause of death)				
0 - 325	9	8,449	1.0+	-
326 - 1,704	11	4,266	2.5	1.0 - 6.0
1,705+	15	4,236	2.0	0.9 - 4.6
		Trend p-value = 0.08		

* RRs are directly adjusted to the age and calendar year distribution of person-years in the referent category.

+ Referent category.

Table III-17

Selected characteristics of subjects with respiratory cancer

Study no.	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m³-days)	GTC work areas	Pre-GTC Employment (m = months y = years)
I. Lung Cancer									
630	1961	39	27	1949-1953	2.6	12	899	UGM	Lead miner-6m; aluminum industry-6m
281	1964	55	39	1948-1951	2.9	16	988	UGM	Road constr. foreman-5y; iron miner-6y
12	1970	63	42	1949-1950	0.05	21	28	Mill: Milling, Maintenance	Unknown
200	1970	45	24	1948-1949	0.15	21	52	UGM	Rock quarryman-1.6y; aluminum industry-5y; iron miner-4m
614	1970	79	57	1948-1948	0.02	21	0	Unexposed	Unknown
50	1971	53	31	1948-1948	0.16	23	54	UGM	Coal company laborer-7m; zinc miner-5m
68	1973	58	34	1948-1949	0.86	24	297	UGM	Talc miner-6m; lead miner-1.2y
659	1973	62	44	1956-1972	17	18	5599	UGM	Farmer-25y
556	1974	54	30	1950-1953	2.5	24	869	UGM	Zinc and lead miner-7y
49	1975	53	26	1948-1948	0.22	27	75	UGM	Machine manufacturing-1y; lead miner-3m; farmer-4m
358	1975	59	36	1953-1964	12	23	4110	UGM	Paper mill machine opr-1y; hosiery mill machine opr-3y; talc miner-12y; constr. warehouse foreman-7m
90	1976	49	25	1952-1969	17	24	7591	Mill: Milling, Labor, Packing, Packhouse support	Paper mill worker-10y

Table III-17, cont.

Study no.	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m^3-days)	GTC work areas	Pre-GTC Employment
610	1979	62	32	1949-1972	23	30	6077	UGM, Minimal	Lead miner-2y; talc mill packerman-1y
695	1980	63	31	1948-1948	0.01	32	2	UGM	Iron miner-2y; farmer-3y; carpenter-1.3y
492	1981	68	35	1949-1951	0.36	33	123	UGM	Talc miner-?y
47	1982	70	37	1949-1951	2.1	33	711	UGM	Unknown
106	1982	75	41	1948-1972	23	34	8942	Mill: Milling, Packhouse support, Maintenance	Clay miner-4y; lead miner-16y
77	1984	77	42	1948-1948	0.21	35	96	Mill: Maintenance	Railroad clerk-4y; lead mine clerk-15y iron mine clerk-3y
155	1984	63	30	1950-1967	17	33	5193	UGM, Minimal exposure	Zinc and lead miner-5y
670	1984	56	23	1951-1951	0.17	33	?	Unknown	Iron miner-6m; lead mine yard work-1y; foundry molder-4m
282	1985	62	25	1948-1949	0.90	37	309	UGM	Iron mine/mill blacksmith, truck driver & miner-3y; painter-5y
584	1985	65	31	1951-1969	17	34	6416	UGM	Aluminum industry-1.2y; feed mill worker-1y
675*	1985	73	36	1948-1949	0.62	37	?	Unknown§	Talc mine constr.-5y; industrial equip. salesman-10+ y
134	1986	68	55	1974-1984	9.9	12	385	Minimal exposure	Paper mill worker-20y; talc mine lab tech & foreman-18y

Table III-17, cont.

Study no.	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m³-days)	GTC work areas	Pre-GTC Employment
193	1986	56	21	1951-1951	0.02	35	0	Unexposed	Hat mfg. machine opr.-5m; engine mechanic-3y;
687	1987	58	25	1954-1954	0.01	33	8	Mill: Milling	Constr. laborer-6m; iron miner-8m; real estate salesman-?y
412	1988	61	47	1974-1974	0.05	14	14	UGM	Groundsman-18y
506	1988	62	23	1948-1971	23	39	0	Unexposed	Paper mill clerk-1.2y; constr. clerk-10m
813	1988	62	22	1948-1948	0.12	40	61	Mill: Labor	Unknown
39	1989	61	26	1954-1958	3.6	35	1237	UGM	Iron miner-3y
343	1989	62	21	1948-1949	0.51	40	249	Mill: Packing	Lead mine yardman, loading shed & tool room worker-3y
II. Larynx Cancer									
806	1979	64	34	1949-1951	1.5	30	514	UGM	Lead miner-4y; talc mill packerman-1y
414	1982	57	23	1949-1949	0.01	14	3	Mill: Packhouse	Unknown
III. Mesothelioma									
351	1968	62	46	1952-1968	15	15	5295	UGM	Carpenter & millwright-16y; lead miner-8y; milk plant repairman-5y
675*	1985	73	36	1948-1949	0.62	37	?	Unknown§	Talc mine constr.-5y; industrial equip. salesman-10+ y

Table III-17, cont.

Study no.	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m^3-days)	GTC work areas	Pre-GTC Employment
IV.	Cancer of Mediastinum								
462	1960	52	47	1954-1959	5.3	5.5	2013	Mill: Maintenance	Foundry molder-?y

* Coded as lung cancer by NYS nosologist and included in analyses as a lung cancer decedent. Medical records indicate mesothelioma as the actual cause of death.

§ No work history record was available. An interview with the next-of-kin indicated that the subject was a draftsman who supervised GTC mill construction and worked outdoors.

Table III-18

Selected characteristics of subjects with NMRD as the underlying cause of death

Study no.	ICD Code	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m^3-days)	GTC work areas	Pre-GTC Employment
I. Pneumonia										
760	485	1961	57	46	1951-1951	0.39	10	134	UGM	Unknown
408	485	1969	82	62	1949-1960	11	20	884	Minimal exposure	Mine shaft constr.-9m
575	486	1972	64	41	1948-1948	0.14	24	66	Mill: Maintenance	Cable making machine operator-2y; bartender-10m
505	485	1973	62	37	1948-1954	5.8	25	2556	Mill: Maintenance	Aluminum products fab. blacksmith-1.7y; aircraft maintenance blacksmith-6m; carpenter-1m
58	486	1976	55	27	1948-1948	0.21	28	18	Minimal exposure	Zinc and lead mine chemist-11m
709	485	1976	74	54	1955-1956	0.19	20	0	Unexposed	Unknown
300	485	1979	54	41	1966-1966	0.53	13	199	Mill: Labor, Milling	Road constr. worker-4y; iron mine lab worker-16y
II. Emphysema										
703	492	1975	49	26	1952-1962	10	23	3974	Mill: Labor, Milling, Packing, Packhouse support; Minimal exposure	Talc miner-5y
272	492	1976	56	34	1953-1970	16	22	5601	UGM	Talc miner-8y
405	492	1982	69	60	1974-1975	1.2	9	53	Minimal exposure	Farm equipment & auto mechanic-5y
285	492	1986	64	26	1948-1949	0.64	38	311	Mill: Packing, Packhouse support	Iron mine truck driver-1y; paper mill machine opr.-4m; meat cutter-10m; copper tube mfg. machine opr.-6m

Table III-18, Cont.

Study no.	ICD Code	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m^3-days)	GTC work areas	Pre-GTC Employment
III. Chronic obstructive pulmonary disease										
267	515	1989	58	37	1968-1969	1.7	21	521	UGM	Talc miner-12y; talc miller-4y
478	515	1989	72	37	1954-1971	17	35	5806	UGM	Zinc miner-1y; lead miner-1y; talc miner-1y
354	519	1975	59	32	1948-1948	0.03	26	2	Minimal exposure	Mine shaft constr.-1.3y
227	519	1978	47	36	1968-1970	2.3	11	645	Mill: Maintenance	Radio mechanic-4y; lead mine electrician-12y; glass works electrician-1y
780	519	1979	65	39	1953-1964	3.0	26	1474	Mill: Milling; Minimal exposure	Tea co. salesman-7y; aluminum smelter furnaceman-2y; mine carpenter & truck driver-4y
621	519	1980	53	21	1948-1949	0.26	31	91	UGM	Iron miner-8m
633	519	1980	71	39	1948-1971	22	32	1983	UGM; Minimal exposure	Textile mfg. machine opr.-2y; iron miner-7y; power plant opr.-2y
IV. Pneumoconiosis and related conditions										
167	517	1961	75	63	1948-1959	10	12	864	Minimal exposure	Milk plant manager-10y
768	515	1968	58	39	1950-1951	1.4	19	492	UGM	Talc mine-2y; lead & zinc mine-9m; constr. foreman-1.3y; iron miner-6m
487	515	1971	57	40	1954-1968	14	17	6064	Mill: Labor, Milling, Maintenance; Unexposed	Quarryman-9y; milk inspector-8y
103	517	1984	64	29	1949-1976	25	35	7526	UGM	Lead miner-1.3y; talc miner-7m; mine shaft constr.-1y
98	515	1988	71	36	1953-1976	23	35	7549	UGM	Iron miner-8y; copper miner-2y

Table III-18, Cont.

Study no.	ICD Code	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m^3-days)	GTC work areas	Pre-GTC Employment
790	519	1980	58	27	1948-1969	21	31	9862	Mill: Milling	Auto mechanic-2y; paper mill worker-2y; zinc and lead miner-1y
548	519	1987	77	43	1954-1956	2.3	33	892	Mill: Labor, Maintenance	Mine & mill constr. & millwright-16y
638	519	1988	65	26	1949-1951	1.7	39	929	Mill: Labor, Milling	Iron miner-6y; mechanic-2.2y
21	519	1989	68	29	1950-1950	0.03	39	?	Unknown	Unknown
600	519	1989	79	38	1948-1973	23	41	3757	UGM; Minimal exposure	Talc co. land salesman-5m

Table III-19

Selected characteristics of subjects with NMRD as a contributory, but not underlying, cause of death

Study no.	ICD Code	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m^3-days)	GTC work areas	Pre-GTC Employment
I. Emphysema										
436	492	1968	55	36	1949-1955	3.4	19	680	Mill: Maintenance	Unknown
704	492	1978	55	30	1953-1978	24	25	7563	UGM	Talc miner-12y
463	492	1980	66	35	1950-1950	0.26	30	?	Unknown	Talc miner-3y
414	492	1982	57	23	1949-1949	0.01	33	2.9	Mill: Packing	Unknown
596	492	1983	63	28	1948-1949	0.21	34	134	Mill: Milling	Paper co. electrician-5y; steel co. electrician-2m; constr. co. foreman-1y
729	492	1985	53	33	1965-1979	6.8	20	628	UGM	Mine engineer-13y
II. Chronic obstructive pulmonary disease										
576	519	1976	63	40	1952-1953	1.2	24	425	UGM	Lead miner-2m; meat cutter-2y
636	519	1981	75	43	1950-1959	9.0	31	3122	UGM	Zinc and lead mining-4m; iron mining-4m
538	519	1982	64	35	1953-1953	0.07	29	?	Unknown	Talc miner-6m
609	519	1985	58	25	1951-1951	0.01	33	?	Unknown	Miner-3m
23	519	1986	69	33	1950-1952	0.95	36	329	UGM	Lead miner-2y
210	519	1986	67	34	1953-1960	6.9	33	2402	UGM	Zinc miner-6y

Table III-19, Cont.

Study no.	ICD Code	Yr. of death	Age at death	Age at hire	Yrs. of hire & termination	Yrs. worked	Yrs. from hire to death	Cum. exp. (mg/m^3-days)	GTC work areas	Pre-GTC Employment
191	519	1987	69	36	1954-1974	20	33	6646	UGM	Farming-5y; talc miner-7y; other mining-3y; constr. worker-2y
687	519	1987	58	25	1954-1954	0.01	33	7.7	Mill: Milling	Constr. laborer-6m; iron miner-8m; real estate salesman-?
III. Pneumoconiosis and related conditions										
732	517	1960	64	56	1952-1952	0.33	8	140	Mill: Maintenance	Paper co.-5m; lead mining-6m talc mining-13y
492	515	1981	68	35	1948-1948	0.36	33	123	UGM	Talc miner-?
106	517	1982	75	41	1948-1972	23	34	8942	Mill: Milling, packhouse support, maintenance	Clay miner-4y; lead miner-16y
650	515	1987	72	33	1948-1976	28	39	9233	Mill: Maintenance	Painter-3y; lineman-8y

APPENDIX A

Original 14 GTC Work Areas
and Typical Component Job Activities

Original 14 GTC Work Areas

Work area	Job activities
1. Mill - Milling	Crusher/dryer operators Wheeler operators Hardinge operators Air process operators Cal process operators Foremen/supervisors/managers
2. Mill - packing/ palletizing	Packers Palletizers
3. Mill - packhouse support	Utility men/pumpmen/laborers Fork lift operators Bulk loaders Foremen/supervisors Car liners
4. Mill - maintenance	Millwirghts Machinists/oilers Electricians Sheet-metal workers/welders Laborer, maint. Instrument repairmen
5. Mill - minimal exposure	Janitors, mill Lab technicians Engineers, mill Draftsmen, mill Stock clerks, mill Property control supervisors Truck drivers, mill
6. Mine 1 - drilling	Drillers Raise borer machine oprs. Machine men
7. Mine 1 - other underground	Blacksmith Cageman Eimco operators Electricians Hoistmen, underground Laborers, underground Maint. mechanics Repairmen Mine foremen Muckers Scrapermen Trammer operators

8.	Mine 1 - surface crushing	Crusher operator #1 Crushermen, surface
9.	Mine 1 - minimal exposure	Engineers, mine Mine superintendents Stock clerks, mine Supply men Watchmen
10.	Mine 2 - equipment operating	Crane operators Drillers, mine 2 Laborers, mine 2 Mobile utility oprs. Tractor operators Truck drivers, mine 2 Repairmen, mine 2
11.	Mine 2 - crushing	Crusher operators, mine 2
12.	Mine 2 - maintenance	Mobile mechanics Hydraulic strip. oprs. Foremen, mine 2
13.	General - minimal exposure	Watchmen, unspecified Janitors, unspecified Managers Personnel & safety dirs.
14.	Unexposed	Carpenters, outside Inventory control supervrs. Mine 4 workers Purchasing agents Accounting clerks Office managers Shipping clerks Laborers, outside

APPENDIX B

Final 12 GTC Work Areas and All Component Job Titles

Job Titles by Work Area

---------------------------- Work Area=Mill-Labor ----------------------------

Job title

LABORER
LABORER TEMP
LABORER
LABORER MILL TEMP
LABORER TEMP.
LABORER
LABORER (PERM.)
LABORER (TEMP)
LABORER (TEMP.)
LABORER (TEMPORARY)
LABORER PERM.
LABORER PERMANENT
LABORER SUMMER HIRE
LABORER TEMP
LABORER TEMP.
LABORER TEMPORARY
LABORER-PERMANENT
LABORER-TEMP.
LABORER-TEMPORARY
PERMANENT LABORER
TEMP. LABORER
TEMPORARY HELP
TEMPORARY LABORER
TEMPORARY SUMMER HELP
LABORER

Job Titles by Work Area

---------------------------- Work Area=Mill-Milling ----------------------------

Job title

SHIFT BOSS
CRUSHER OPR.
HARDINGE OPR.
#1 CRUSHER OPR.
1ST MILLER
1ST MILLER (SC)
1ST MILLER SC
1ST MILLER WHEELER
2ND MILLER
ASST MILL SUPT
C.P. OP. #2
C.P. OP. NO. 1
C.P. OPERATOR
C.P. OPERATOR #1
C.P. OPERATOR #2
CAL PROCESS OP. #I
CAL PROCESS OP. #II
CAL. PROC. OP. #II
CAL. PROCESS OP.
CAL. PROCESS OP. #1
CAL. PROCESS OP. #II
CALIFORNIA PROCESS OP #1
CALIFORNIA PROCESS OP #2
CALIFORNIA PROCESS OP. #I
CALIFORNIA PROCESS OP. #II
CALIFORNIA PROCESS OPR. II
CRUSHER #1 OPR.
CRUSHER OP
CRUSHER OP.
CRUSHER OP. (TEMP.)
CRUSHER OPER. #3 PERM.
CRUSHER OPER. #3 TEMP.
CRUSHER OPER. TEMP.
CRUSHER OPERATOR
CRUSHER OPERATOR #1
CRUSHER OPERATOR #1 PERM
CRUSHER OPERATOR #1 PERMANENT
CRUSHER OPERATOR #1 TEMP
CRUSHER OPERATOR #1-PERMANENT
CRUSHER OPERATOR #1-TEMP.
CRUSHER OPERATOR #3
CRUSHER OPERATOR #3 - TEMP.
CRUSHER OPERATOR #3 TEMP
CRUSHER OPERATOR #3 TEMP.
CRUSHER OPERATOR #3-TEMP
CRUSHER OPERATOR (TEMP)
CRUSHER OPERATOR (TEMP.)
CRUSHER OPERATOR PERMANENT
CRUSHER OPERATOR TEMP
CRUSHER OPERATOR TEMP.
CRUSHER OPR #1
CRUSHER OPR.
CRUSHER OPR. #1
CRUSHER OPR. #3

---------------------------- Work Area=Mill-Milling ----------------------------
(continued)

Job title

CRUSHER OPR. #3 - TEMP
CRUSHER OPR. TEMP #3
CRUSHER OPR. TEMP.
CRUSHERMAN
CRUSHERMAN #1
CRUSHERMAN PERMANENT
CRUSHERMAN TEMP.
CRUSHERMAN TEMP. #1
FIRST MILLER
FOREMAN
HARDINGE MILLER
HARDINGE OP.
HARDINGE OP. & LABORER
HARDINGE OPER #4-5-6 (PERM)
HARDINGE OPER.
HARDINGE OPER. #1
HARDINGE OPER. #1,2,3 TEMP.
HARDINGE OPER. #4,5,6
HARDINGE OPER. #4-5-6 (TEMP)
HARDINGE OPER. 4-5-6
HARDINGE OPERATOR
HARDINGE OPERATOR #1
HARDINGE OPERATOR #1,2,3
HARDINGE OPERATOR #1,2,3 (PERM.)
HARDINGE OPERATOR #1,2,3 TEMP.
HARDINGE OPERATOR #1-2-3
HARDINGE OPERATOR #4,5,6
HARDINGE OPERATOR #4,5,6 TEMP
HARDINGE OPERATOR #4,5,6 TEMP.
HARDINGE OPERATOR #4-5-6
HARDINGE OPERATOR 1-2-3
HARDINGE OPERATOR TEMP
HARDINGE OPERATOR TEMP.
HARDINGE OPR.
HARDINGE OPR. #1
HARDINGE OPR. #1,2,3
HARDINGE OPR. #1,2,3 PERM.
HARDINGE OPR. #2
HARDINGE OPR. #3
HARDINGE OPR. #4,5 PERM.
HARDINGE OPR. #4,5,6
HARDINGE OPR. #4-5-6 (TEMP)
HARDINGE OPR. TEMP
HARDINGE OPR. TEMP.
HARDINGE OPR. TEMPORARY
HDGE. OPER.
HDGE. OPR. TEMP.
LABORER & HARDING SWING OPERATOR
LABORER/HARDINGE OPERATOR
MILL SHIFT FOREMAN
MILL SUPERINTENDENT
MILL SUPT.
MILLER

Job Titles by Work Area

---------------------------- Work Area=Mill-Milling ----------------------------
(continued)

Job title

MILLING OPERATOR
PRO. AIR ENG.
PROCESS AIR ENG
PROCESS AIR ENG.
PROCESS AIR ENGINEER
PROCESS AIR OPER
PROCESS AIR OPERATOR
SECOND MILLER
SHIFT FOREMAN
SHIFT FOREMAN TEMP
SUBSTITUTE SHIFT FOREMAN
SUMMER HELP
SUPERINTENDENT
TEMP. CRUSHER OP.
TEMPORARY 1ST MILLER-WHEELER
WHEELER MILL OPR.
WHEELER MILLER
WHEELER OP
WHEELER OPER.
WHEELER OPER. TEMP.
WHEELER OPERATOR
WHEELER OPERATOR #1
WHEELER OPERATOR TEMP
WHEELER OPERATOR TEMP.
WHEELER OPERATOR TEMPORARY
WHEELER OPR. #1
WHEELER OPR. PERM.
WHEELER OPR. TEMP.
WHEELER OPR.-TEMP.
CRUSHER OPERATOR
CRUSHER OPERATOR #3
HARDINGE OPERATOR #3
HARDINGE OPR. #3
MILL SHIFT FOREMAN
MILLING OPER.
MILLING OPER. #3 PERM.
MILLING OPERATOR
MILLING OPERATOR #3
MILLING OPERATOR #3 (PERM.)
MILLING OPERATOR #3 PERM.
MILLING OPERATOR #3 PERMANENT
MILLING OPERATOR #3 TEMP
MILLING OPERATOR #3 TEMP.
MILLING OPR.
MILLING OPR. #3
MILLING OPR. TEMP.
HARDINGE OPR.
HARDINGE OPR. TEMP.
MILL FOREMAN
MILL SHIFT FOREMAN - #3
MILL SUPERINTENDENT

Job Titles by Work Area

------------------------------ Work Area=Mill-Packing ------------------------------

Job title

#2 PACKERMAN TEMP.
LABORER PACKING
PACKER
PACKER #1
PACKER #1 TEMP
PACKER #1 TEMP.
PACKER #2 STATION
PACKER #3
PACKER #3 ST.
PACKER #3 STATION
PACKER #4
PACKER #5
PACKER - CREW #1 PERM.
PACKER 3 MAN CREW
PACKER CREW #1
PACKER CREW #1 PERMANENT
PACKER CREW #2
PACKER CREW #2 TEMP
PACKER CREW #3
PACKER CREW #3 PERM.
PACKER CREW #4
PACKER CREW #5
PACKER LEADMAN
PACKER NO. 2 STATION
PACKER NO. 3 STATION
PACKER PERMANENT
PACKER TEMP
PACKER TEMP.
PACKER TEMP. CREW #5
PACKER TEMPORARY
PACKER-CREW #2
PACKER-LABORER TEMP
PACKER/LABORER
PACKERMAN
PACKERMAN - CREW #1
PACKERMAN CREW #1
PACKERMAN CREW #1 TEMP
PACKERMAN CREW #2
PACKERMAN CREW #3
PACKERMAN CREW #3 TEMP.
PACKERMAN-CREW #1
PACKER TEMP.
PACKER TEMP

Job Titles by Work Area

--------------------- Work Area=Mill-Packhouse support ---------------------

Job title

FORK LIFT OPERATOR
PACKHOUSE UTILITYMAN
ASSISTANT PACKHOUSE FOREMAN
CAR LINER
CAR-TRUCK LINER/LOADER
CHECK WEIGHMAN & UTILITYMAN
CHECKWEIGHMAN
CHECKWEIGHMAN(PACKER SERVICEMAN)
CLEAN-UP MAN
CLEANUP MAN
CLEANUP TEMPORARY
F-K MAN
F-K PUMP MAN
F-K PUMPMAN
F.K. PUMP MAN
F.K. PUMPMAN
F.L. OPERATOR
FK MAN
FORK LIFT OP & WAREHOUSEMAN
FORK LIFT OPERATOR
FORKLIFT OP.
FORKLIFT OPER.
FORKLIFT OPERATOR
FORKLIFT OPERATOR TEMPORARY
FULLER KINYON OP.
FULLER KINYON OPERATOR
FULLER-KINYON MAN
FULLER-KINYON OPR.
MATERIAL HANDLING UTILITYMAN
MATERIAL HANDLING UTILITYMAN #1
MILL PACKING & LOADING FOREMAN
PACKER SERVICE MAN
PACKER SERVICEMAN
PACKER SERVICEMAN #1
PACKER SERVICEMAN #3 TEMP.
PACKER SERVICEMAN (TEMP.) & WHEELER OPER.
PACKER SERVICEMAN (TEMPORARY)
PACKER SERVICEMAN CREW #1
PACKER SERVICEMAN CREW #2
PACKHOUSE FOREMAN
PACKHOUSE HELPER
PACKHOUSE LEADER
PACKHOUSE SERVICE/U[illegible]
PACKHOUSE UTILITY
PACKHOUSE UTILITY MAN
PACKHOUSE UTILITY OPER. [illegible]
PACKHOUSE UTILITY/LABORER
PACKHOUSE UTILITYMAN
PACKHOUSE UTILITY.MAN [illegible]
PACKHOUSE UTILITYMAN #1 PERM.
PACKHOUSE UTILITYMAN #1 TEMP
PACKHOUSE UTILITYMAN #1-[illegible]
PACKHOUSE UTILITYMAN #2
PACKHOUSE UTILITYMAN #3

---------------------- Work Area=Mill-Packhouse support ----------------------
(continued)

Job title

PACKHOUSE UTILITYMAN #4
PACKHOUSE UTILITYMAN #5
PACKHOUSE UTILITYMAN - #1 CREW
PACKHOUSE UTILITYMAN CREW #1
PACKHOUSE UTILITYMAN CREW #2
PACKHOUSE UTILITYMAN TEMP.
PACKHOUSE UTILITYMAN-CREW #3
PACKHOUSE UTILTYMAN #4
PACKING & LOADING FOREMAN
STENCIL MAN
STENCIL MAN & CHECKWEIGHMAN #3 ST
STENCIL-MAN
STENCILMAN
STENCILMAN & CHECKWEIGHMAN
STENCILMAN AND CHECKWEIGHMAN
UTILITY MAN
UTILITYMAN TEMPORARY
BULK LOADER - UTILITYMAN
BULK LOADER OPR.-UTILITYMAN
BULK LOADER-UTILITYMAN-TEMP.
BULK LOADER/UTILITYMAN TEMP.
FORKLIFT OPR #3
PACKER SERVICEMAN
PACKHOUSE UTILITYMAN

Job Titles by Work Area

------------------------- Work Area=Mill-Maintenance --------------------------

Job title

2ND CLASS WELDER
APPRENTICE ELECTRICIAN
CHIEF ELECTRICIAN
ELECTRICIAN
ELECTRICIAN - 1ST CLASS
ELECTRICIAN 1ST CLASS
ELECTRICIAN 2ND C.
ELECTRICIAN APPRENTICE
ELECTRICIAN FOREMAN OF MILLS
ELECTRICIAN HLPR.
ELECTRICIAN INTERMEDIATE
ELECTRICIAN LDR.
ELECTRICIAN STANDARD
ELECTRICIAN STARTER
ELECTRICIAN STARTING
ELECTRICIAN STD.
ELECTRICIAN-APPRENTICE
FOREMAN IRON WORKERS
INSTRUMENT MAN
INSTRUMENT REPAIRMAN
IRON WORKER
MACHINIST
MACHINIST 1ST CLASS
MACHINIST LEADER
MACHINIST'S HELPER
MAINTENANCE FOREMAN
MAINTENANCE WELDER
MILL ELECTRICAL FOREMAN
MILL MAINTENANCE FOREMAN
MILLWRIGHT
MILLWRIGHT (INTERMEDIATE)
MILLWRIGHT (STANDARD)
MILLWRIGHT (STARTING)
MILLWRIGHT (TEMP)
MILLWRIGHT 1ST C.
MILLWRIGHT 1ST CLASS
MILLWRIGHT APP.
MILLWRIGHT APPRENTICE
MILLWRIGHT APPRENTICE STARTER
MILLWRIGHT HELPER
MILLWRIGHT INTERMEDIATE
MILLWRIGHT STANDARD
MILLWRIGHT STANDARD & MACHINIST APPRENTICE
MILLWRIGHT STARTER
MILLWRIGHT STARTING
MILLWRIGHT STD.
MILLWRIGHT TEMPORARY
MILLWRIGHT-APPRENTICE
MTN. MILLWRIGHT
OILER
OILER (TEMP.)
OILER TEMP.
OILER TEMPORARY
OILER-SENIOR

Job Titles by Work Area

Work Area=Mill-Maintenance (continued)

Job title

PAINTER
PIPE FITTER LEADER
PLANT ELECTRICIAN
REPAIRMAN
SHEET METAL MAN TEMP
SHEET METAL WORKER
SHEETMETAL WORKER
TEMP. ELEC.
TEMPORARY MAINTENANCE WELDER
WELDER
WELDER (TEMP.)
WELDER 1ST CLASS
WELDER 2ND CLASS
WELDER APPRENTICE
WELDER INTERMEDIATE
WELDER STANDARD
WELDER STARTING
WELDER TEMPORARY
WELDER, 2ND CLASS
MILLWRIGHT APPRENTICE

Job Titles by Work Area

------------------------ Work Aréa=Minimal exposure ------------------------

Job title

ASSISTANT MINE SUPERINTENDENT
ASSISTANT SURVEYOR
ASST MINE ENGINEER TEMP
CHIEF ENGINEER
ENGINEER
ENGINEER'S AID
ENGINEER'S HELPER TEMPORARY
ENGINEERING TECHNICIAN
GEOLOGIST
HOIST HOUSE ENG.
HOIST HOUSE ENGINEER
HOISTHOUSE ENG.
HOISTMAN
HOISTMAN TEMP.
HOISTMAN-SURFACE
JR. GEOLOGIST
MINE CONSTR. LABOR (TEMP)
MINE CONSTR. LABOR TEMP
MINE ENGINEER
MINE ENGINEER ASSISTANT
MINE ENGINEER'S ASST.
MINE STOCK CLERK
PROJECT ENGINEER
STOCK CLERK - U.G.
STOCK CLERK TEMP.
STOCK CLERK U.G.
STOCK CLERK UG
STOCK CLERK-U.G.
STOCK CLERK-UG
STOREKEEPER
SUPPLY MAN
U.G. STOCK CLERK
WATCHMAN
JANITOR
JANITOR TEMP.
JANITOR TEMPORARY
TEMP. JANITOR
ASST DRAFTSMAN
ASST. LAB TECH.
DRAFTSMAN
ENGINEERING TECHNICIAN
JANITOR
JANITOR PERMANENT
JANITOR TEMP.
JANITOR TEMPORARY
LAB ASSISTANT
LAB ASSISTANT (TEMP)
LABORATORY ASSISTANT
LABORATORY TECH. TEMP.
LABORATORY TECHNICIAN
LABORER & TEMP. LAB. TECH.
MAINTENANCE DIRECTOR
MILL - LAB ASSISTANT
MILL ENGINEER

Job Titles by Work Area

------------------------- Work Area=Minimal exposure -------------------------
(continued)

Job title

MILL TECHNICIAN
QUALITY CONT TECH
QUALITY CONT TECHNICIAN TEMP.
QUALITY CONT. TECH. #3
QUALITY CONT. TECH. #4
QUALITY CONT. TECH. TEMP.
QUALITY CONT. TECHNICIAN TEMP
QUALITY CONTROL
QUALITY CONTROL (TEMP)
QUALITY CONTROL - LAB
QUALITY CONTROL PERMANENT
QUALITY CONTROL SUBSTITUTE
QUALITY CONTROL TECH
QUALITY CONTROL TECH #1
QUALITY CONTROL TECH #1 TEMP
QUALITY CONTROL TECH #3
QUALITY CONTROL TECH #4
QUALITY CONTROL TECH PERMANENT
QUALITY CONTROL TECH TEMP
QUALITY CONTROL TECH.
QUALITY CONTROL TECH. #1
QUALITY CONTROL TECH. #2
QUALITY CONTROL TECH. #4
QUALITY CONTROL TECH. (TEMP)
QUALITY CONTROL TECH. PERM. #1
QUALITY CONTROL TECH. PERM. #2
QUALITY CONTROL TECH. PERM. #3
QUALITY CONTROL TECH. TEMP
QUALITY CONTROL TECH. TEMP.
QUALITY CONTROL TECH. TEMP. #1
QUALITY CONTROL TECH. TEMP. #2
QUALITY CONTROL TECHNICIAN
QUALITY CONTROL TECHNICIAN #1
QUALITY CONTROL TECHNICIAN #2
QUALITY CONTROL TECHNICIAN #3
QUALITY CONTROL TECHNICIAN #4
QUALITY CONTROL TECHNICIAN TEMP.
QUALITY CONTROL TEMP.
STOCK CLERK
STOCK CLERK & MACHINIST HELPER
STOCK CLERK SENIOR
STOCK CLERK TEMP.
STOREKEEPER
SUBSTITUTE LABORATORY TECH
SUPERVISOR OF QUALITY CONTROL
SUPERVISOR PROPERTY CONTROL MILL
SUPERVISOR QUALITY CONTROL
TEMPORARY JANITOR
TEMPORARY LABORATORY TECH
TRUCK DRIVER & UTILITY - Mill
TRUCK DRIVER (SENIOR) - Mill
TRUCK DRIVER - Mill
TRUCK DRIVER SR. - Mill

Job Titles by Work Area

------------------------- Work Area=Minimal exposure -------------------------
(continued)

Job title

UNASSIGNED
UNKNOWN
WATCHMAN
WATCHMAN PART-TIME
WATCHMAN TEMPORARY
JANITOR
JANITOR PERMANENT
JANITOR TEMP
WATCHMAN
ASSISTANT MANAGER
ASSISTANT MANAGER CHIEF ENGINEER
ASSISTANT MANAGER-ENGINEERING
ASST. PERSONNEL & SAFETY DIRECTOR
GENERAL MANAGER
PERSONNEL & SAFETY DIRECTOR
SAFETY & PERSONNEL DIRECTOR
STOCK CLERK & MACHINIST'S HELPER
VICE PRESIDENT AND GENERAL MANAGER
CARETAKER
WATCHMAN
WATCHMAN PART-TIME
WATCHMAN PERM.
WATCHMAN PERMANENT
WATCHMAN TEMP
WATCHMAN TEMPORARY
WATCHMAN-PERM.
WATCHMAN-TEMP.
WATCHMAN

Job Titles by Work Area

------------------------- Work Area=Mine 1-Underground -------------------------

Job title

APPR'T DRILLER
APPRENTICE DRILLER
ASST. MINE FOREMAN
BLACKSMITH
BLACKSMITH & WELDER
BLACKSMITH HELPER
BLACKSMITH/WELDER
CAGEMAN
DIAMOND DRILLER
DIAMOND DRILLER TEMP.
DRILLER
DRILLER #1
DRILLER - U.G.
DRILLER NO. 1
DRILLER SHAFT
DRILLER SHAFT TEMP
DRILLER SHAFT TEMP.
DRILLER TEMP.
DRILLER TEMPORARY
DRILLER U.G.
DRILLER'S HELPER
DRILLER, TEMP.
DRILLER-SHAFT
DRILLER-SHAFT (TEMP.)
DRILLER-U.G.
DRILLERS HELPER
EIMCO
EIMCO MAN
EIMCO MAN (TRAMMER)
EIMCO OP.
EIMCO OP. (TRAMMER)
EIMCO OPER.
EIMCO OPERATOR
ELECTRICIAN
ELECTRICIAN APP.
ELECTRICIAN APPRENTICE
ELECTRICIAN INTERMEDIATE
ELECTRICIAN STANDARD
ELECTRICIAN STARTING
ELECTRICIAN STD
GENERAL MINE FOREMAN
GENERAL MINE MAINTENANCE FOREMAN
GRIZZLYMAN
HOISTMAN U.G.
HOISTMAN-U.G.
LABORER
LABORER - TEMP.
LABORER - U.G.
LABORER - UNDERGROUND
LABORER MINE TEMP
LABORER PERM
LABORER PERM.
LABORER PERMANENT
LABORER TEMP

------------------------- Work Area=Mine 1-Underground -------------------------
(continued)

Job title

LABORER TEMP.
LABORER TEMPORARY
LABORER U.G.
LABORER U.G. #1
LABORER U.G. #4
LABORER U.G. (TEMP)
LABORER U.G. PERM.
LABORER U.G. PERMANENT
LABORER U.G. TEMP
LABORER U.G. TEMP.
LABORER UG
LABORER, U.G.
LABORER-TEMP.
LABORER-TEMPORARY
LABORER-U.G.
LABORER-UG
LOADERSHOVEL OPERATOR
LOADERSHOVELMAN
MACHINE MAN
MACHINE-MAN
MAINT. MECH
MAINT. MECH.
MAINT. MECH. #1
MAINT. MECH. #4
MAINT. MECH. INTER.
MAINT. MECH. INTERMEDIATE
MAINT. MECH. STARTER
MAINT. MECH. STD.
MAINT. MECH. STR
MAINT. MECH. STR.
MAINT. MECHANIC
MAINT. MECHANIC INT.
MAINT. MECHANIC STARTER
MAINT. MECHANIC STD.
MAINTENANCE MECH.
MAINTENANCE MECH. INT.
MAINTENANCE MECH. STARTER
MAINTENANCE MECH. STD.
MAINTENANCE MECHANIC
MAINTENANCE MECHANIC APPRENTICE
MAINTENANCE MECHANIC INT.
MAINTENANCE MECHANIC STARTER
MAINTENANCE MECHANIC STD.
MECHANIC'S HELPER
MID-TERM HELP
MINE FOREMAN
MINE LABORER U.G.
MINE MAINTENANCE FOREMAN
MINE SHIFT BOSS
MINE SHIFT FOREMAN
MINE SUPERINTENDENT
MINE SUPERINTENDENT & ASST RESIDENT MANAGER
MINER TEMP.

Job title

MOTORMAN
MUCKER
MUCKER TEMP
MUCKER, DRILLER, REPAIRMAN
NIGHT SHIFT BOSS
NIGHT SHIFT BOSS (TEMP.)
PERMANENT LABORER U.G.
RAISE BORE MACHINE HELPER
RAISE BORER MACH. HLPR. OPR
RAISE BORER MACH. OPR.
RAISE BORER MACHINE HELPER
RAISE BORER MACHINE OPERATOR
RAISE BORER MACHINE OPR.
RAISE BORING MACHINE HELPER
RAISE MACHINE HELPER
RAISE MACHINE OPERATOR
RAISE MACHINE OPERATOR TEMPORARY
REPAIRMAN
REPAIRMAN #1
REPAIRMAN HELPER
REPAIRMAN STD.
REPAIRMAN TEMP
REPAIRMAN TEMPORARY
REPAIRMAN U.G.
REPAIRMAN'S HELPER
SCRAPER MAN
SCRAPER OP.
SCRAPER OPER.
SCRAPER OPERATOR
SCRAPERMAN
SCRAPERMAN (TRAMMER)
SHAFT DRILLER
SHAFT MUCKER
SHIFT BOSS
SHIFT FOREMAN
SUMMER HELP
TEMPORARY LABORER U.G.
TRACTOR OPR. LDR.
TRAMMER
TRAMMER (TEMP)
TRAMMER (TEMP.)
TRAMMER - TEMPORARY
TRAMMER PERM.
TRAMMER PERMANENT
TRAMMER TEMP
TRAMMER TEMP.
TRAMMER TEMPORARY
TRAMMER-TEMP
TRAMMER-TEMP.
TRAMMER/LABORER
TRAMMER/LABORER TEMP.
U.G. HOISTMAN
U.G. HOISTMAN TEMP.

------------------------- Work Area=Mine 1-Underground -------------------------
(continued)

Job title

U.G. LABORER
UNDERGROUND HOISTMAN
UNKNOWN
UTILITY MAN

Job Titles by Work Area

---------------------- Work Area=Mine 1-Surface Crushing ------------------------

Job title

CRUSHER OPERATOR #1
CRUSHERMAN
CRUSHERMAN #1
CRUSHERMAN - MN
CRUSHERMAN SURF. TEMP.
CRUSHERMAN SURFACE
CRUSHERMAN SURFACE TEMP
CRUSHERMAN-SURFACE
CRUSHERMAN-SURFACE-TEMP.

Job Titles by Work Area

---------------- Work Area=Mine 2-Equipment Operating --------------------

Job title

CRANE OPERATOR
CRANE OPR. #2 MINE
DRILLER
DRILLER - OP
DRILLER - OP TEMP
DRILLER - OPEN PIT
DRILLER O.P.
DRILLER O.P. TEMP.
DRILLER OP
DRILLER OP TEMP
DRILLER OPEN PIT
DRILLER TEMP. O.P.
DRILLER-O.P.
DRILLER-OP
LABORER
LABORER (OPEN PIT)
LABORER - OP
LABORER -OP
LABORER O.P.
LABORER O.P. PERMANENT
LABORER O.P. TEMP
LABORER TEMP.
LABORER-O.P. (TEMP.)
MOBILE UITLITY OPERATOR #2
MOBILE UTIL OPERATOR
MOBILE UTIL OPR TEMP
MOBILE UTIL. OPER.
MOBILE UTIL. OPR.
MOBILE UTIL. OPR. #2-TEMP.
MOBILE UTIL. OPR. #4
MOBILE UTILITY OPERATOR #2
MOBILE UTILITY OPER
MOBILE UTILITY OPER.
MOBILE UTILITY OPER. #4
MOBILE UTILITY OPER. TEMP.
MOBILE UTILITY OPERATOR
MOBILE UTILITY OPERATOR #2
MOBILE UTILITY OPERATOR #4
MOBILE UTILITY OPERATOR TEMP
MOBILE UTILITY OPR.
MOBILE UTILITY OPR. #1
MOBILE UTILITY OPR. #2
MOBILE UTILITY OPR. (TEMP.)
MOBILE UTILITY OPR. TEMP
MOBILE UTILITY OPR. TEMP.
REPAIRMAN O.P.
REPAIRMAN OP
REPAIRMAN-OP
TRACTOR LOADER OPR.
TRACTOR OPERATOR (LDR)
TRACTOR OPERATOR (LDR.)
TRACTOR OPERATOR (LDR.) TEMP.
TRACTOR OPERATOR LDR
TRACTOR OPERATOR LDR.

--------------------- Work Area=Mine 2-Equipment Operating ---------------------
(continued)

Job title

TRACTOR OPERATOR LOADER
TRACTOR OPERATOR LOADER (PERM.)
TRACTOR OPERATOR LOADER (TEMP.)
TRACTOR OPR LDR.
TRACTOR OPR. (LDR.)
TRACTOR OPR. LDR.
TRACTOR OPR. LOADER
TRUCK DRIVER - O.P.
TRUCK DRIVER O.P.
TRUCK DRIVER O.P. - TEMP
TRUCK DRIVER O.P. TEMP
TRUCK DRIVER O.P. TEMP.
TRUCK DRIVER O.P. TEMPORARY
TRUCK DRIVER OP TEMP
TRUCK DRIVER PROD.
TRUCK DRIVER PROD. (OPEN PIT)
TRUCK DRIVER PROD. TEMP.
TRUCK DRIVER PRODUCTION
TRUCK DRIVER PRODUCTION TEMP
TRUCK DRIVER PRODUCTION TEMP.
TRUCK DRIVER PRODUCTION TEMPORARY
TRUCK DRIVER TEMP.
TRUCK DRIVER TEMP.-O.P.
TRUCK DRIVER-OP
TRUCK DRIVER-OP (TEMP)
TRUCK DRIVER-PRODUCTION
TRUCK DRIVER-PRODUCTION (O.P.)
TRUCK DRIVER-PRODUCTION (OP)
TRUCK DRIVER-PRODUCTION OP
TRUCK DRIVER-PRODUCTION-TEMP.
TRUCK DRIVER-TRACTOR TRAILER
TRUCKER DRIVER OPEN PIT

Job Titles by Work Area

------------------------- Work Area=Mine 2-Crushing ---------------------------

Job title

CRUSHER OPERATOR
CRUSHER OPERATOR O.P.
CRUSHER OPERATOR OP TEMP
CRUSHER OPERATOR-OP
CRUSHER OPR.-O.P.
CRUSHER TRACTOR OPR. LDR.
CRUSHERMAN O.P.
CRUSHERMAN OP
CRUSHERMAN OP PERMANENT
CRUSHERMAN OP TEMP
CRUSHERMAN TEMP. #2
CRUSHERMAN TRACTOR LDR. OPR. - OP
CRUSHERMAN TRACTOR OPR. LDR.
CRUSHERMAN-TEMP.
CRUSHERMAN-TRACTOR OPR. LDR.
CRUSHERMAN-TRACTOR-OPR. LDR.

Job Titles by Work Area

------------------------ Work Area=Mine 2-Maintenance ------------------------

Job title

#2 MINE FOREMAN
EQUIPMENT MAINTENANCE FOREMAN
HYDRAULIC STRIPPING HELPER
HYDRAULIC STRIPPING PUMP OPR.
HYDRAULIC STRIPPING PUMP OPR. TEMP
MINE FOREMAN
MINE SHIFT FOREMAN - OP
MINE SHIFT FOREMAN-OP
MOBILE EQUIP. MECH. STARTING
MOBILE EQUIP. MECHANIC APPRENTICE
MOBILE EQUIPMENT MECHANIC
MOBILE EQUIPMENT MECHANIC APPRENTICE
OPEN PIT FOREMAN

Job Titles by Work Area

------------------------------ Work Area=Unexposed ------------------------------

Job title

SUPERVISOR OF INVENTORY CONTROL
CARPENTER
CARPENTER TEMP
SURVEYOR
CRUSHERMAN #4 - Mine 4
CRUSHERMAN #4 TEMP - Mine 4
CRUSHERMAN #4 TEMP. - Mine 4
CRUSHERMAN #4-TEMP. - Mine 4
DRILLER - Mine 4
LABORER - Mine 4
MINE FOREMAN - Mine 4
MINE SHIFT BOSS - Mine 4
MINER #4 (TEMP.) - Mine 4
MINER #4 - Mine 4
MINER #4 PERM. - Mine 4
MINER #4 PERMANENT - Mine 4
MINER #4 TEMP - Mine 4
MINER TEMP. #4 - Mine 4
MOBILE UTIL. OPER. - Mine 4
MOBILE UTIL. OPR. TEMP. - Mine 4
MOBILE UTILITY OPER. - Mine 4
MOBILE UTILITY OPERATOR #4 - Mine 4
MOBILE UTILITY OPR - Mine 4
MOBILE UTILITY OPR. #4 - Mine 4
MOBILE UTILITY OPR. - Mine 4
MOBILE UTILITY OPR. TEMP. - Mine 4
REPAIRMAN OP/TRACTOR OPERATOR LOADER - Mine 4
REPAIRMAN OP/TRACTOR OPR. LDR. - Mine 4
TRACTOR OPERATOR (LDR.) - Mine 4
TRACTOR OPERATOR LDR - Mine 4
TRACTOR OPERATOR LDR. - Mine 4
TRACTOR OPERATOR LOADER - Mine 4
PURCHASING AGENT
SUPERVISOR INVENTORY CONTROL
SUPERVISOR OF INVENTORY CONTROL
SUPERVISOR OF INVENTORY CONTROL
ACCOUNTS PAYABLE CLERK
CHIEF ACCOUNTANT & OFFICE MANAGER
CHIEF ACCOUNTANT/OFFICE MANAGER
CLERK
ELECTRICAL CONSULTANT
INVENTORY CONTROL CLERK
OFFICE MANAGER
PERSONNEL ADMINISTRATOR
PURCHASING AGENT
RECEPTIONIST
SECRETARY & SHIPMENT CLERK
SHIPPING & INVENTORY COORDINATOR
SHIPPING CLERK
CONTRACT LIMB CUTTER
LABORER
MASON
SURFACE LABOR