MORTALITY OF STEELWORKERS EMPLOYED IN HOT JOBS

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The possible relationships between heat stress and cause-specific mortality patterns were analyzed in a cohort of 59,414 steelworkers employed in jobs involving heat exposure. A deficit mortality from cardiovascular disease for workers in jobs involving higher levels of environmental heat exposure was determined. The high risk of death for workers with less than 6 months of exposure and a downward trend in mortality for workers who remained on the job, are indicative of a possible relationship between inability to work in jobs involving heat stress and health. An increased risk of non-malignant digestive disease mortality was recorded for the group of workers exposed to higher levels of environmental heat, especially after excluding liver cirrhosis.

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List of Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
CVR	Cardiovascular-Renal Disease
DB	Dry-Bulb Temperature Outside a Plant
DBA	Dry-Bulb Temperature at Greater Pittsburgh International Airport
GT	Globe Temperature at Worksite
ICD	International Classification of Diseases
NWB	Natural Wet-Bulb Temperature Outside a Plant
PWBA	Psychrometric Wet-Bulb Temperature at Greater Pittsburgh International Airport
RR	Relative Risk
R^2	Coefficient of Multiple Determination
SPSS	Statistical Package for the Social Sciences
TLV	Threshold Limit Value
WBGT	Wet-Bulb-Globe Temperature at Worksite

ABSTRACT

This study investigates possible relationships between heat stress of steelworkers and cause-specific mortality patterns. Prior to field investigation, jobs were identified which appeared to involve heat stress exposure. A selected sample of these jobs, was surveyed for assessing the workers environmental and metabolic heat load. These data were utilized to form different categories of heat stress.

Mortality patterns of workers in jobs falling in each of the heat stress categories were analyzed by length of exposure for workers in a cohort of 59,414 steelworkers who held one of the surveyed jobs. The control population consisted of workers who never worked in any of the work areas in which jobs were surveyed but were members of the same cohort. Findings of interest are:

(1) a deficit in mortality from cardiovascular disease for workers in jobs involving higher levels of environmental heat exposure;

(2) a high risk of death from cardiovascular disease for workers with less than 6 months of exposure and a downward trend in mortality for workers who remained on the job, indicating a possible relationship between inability to work in jobs involving heat stress and health; and

(3) increased risks of nonmalignant digestive disease mortality for this same group of workers exposed to higher levels of environmental heat, especially after excluding cirrhosis of the liver.

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INTRODUCTION

Background

The NIOSH criteria document for heat stress notes the need for epidemiological studies relating long-term occupational heat stress exposure to morbidity and mortality (1). The short-term effects of heat stress have been studied extensively, particularly with respect to the cardiovascular system. However, no studies exist which can provide information useful in determining whether any health hazards exist following long-term heat exposures. It is especially important to investigate individual and interactive effects of the principal components of heat stress: environmental and metabolic heat load.

Since 1961, the Department of Biostatistics, Graduate School of Public Health, University of Pittsburgh, has been carrying out a longitudinal study of the mortality experience of all men employed at seven steel plants in Allegheny County, Pennsylvania (2, 3). This study has focused on the examination of the relationships between the cause specific mortality patterns and various work exposures in the steel industry. Through 1970, almost 13,000 deaths have occurred among the approximately 59,000 men working in the plants in 1953. In the research presented here, a field investigation of environmental heat stress and activity has followed for mortality, thus providing information relative to the possible effects of long-term work in hot environments.

Purpose

The purpose of this study was to investigate the relationships between heat stress and cause-specific mortality in a large cohort of steelworkers.

Specific questions investigated included:

(1) Do mortality patterns differ among workers with different levels of environmental heat exposure and work load?

(2) Are there differences in mortality according to the length of time spent in hot jobs?

(3) If mortality differences are noted between heat exposed and non-heat exposed workers, what other factors, such as job exposures other than heat, may be important in explaining the results?

FIELD INVESTIGATIONS

Selection of Jobs

Jobs were selected for field study from the cohort of the long-term study of mortality of steelworkers (2, 3). For each man, a complete work history from date of first employment through 1970 is known, as well as information on vital status from 1953 through 1970, including date and cause of death, when applicable. Approximately 7,000 jobs, which were distributed among 57 "work areas," were represented in that study. In general, work areas may be defined as consisting of either a group of men responsible for certain related tasks, e.g., Mason Department, or a section of the plant in which a particular process occurs, e.g., Blast Furnace. These work areas may be classified broadly into groups responsible for 1) iron and steel production, 2) steel finishing, 3) plant maintenance, and 4) administrative, clerical, and technical work. Since each man in this study was employed in 1953, the 1953 edition of the Job Description and Classification Manual for the steel industry was utilized to assist in the classification of the jobs (4). This manual, which is used primarily in the steel industry for setting wage levels, includes a brief description of duties for each job, and also gives a subjective evaluation of surroundings and possible hazards entailed in the job. A sample page from this Manual and definitions of codes and numerical classifications used in the Manual for the severity of the workers' exposure to environmental stresses are shown in Tables 1 and 2.

Since data from this steelworkers' cohort were to be utilized in the present study, the manual was used to identify jobs involving heat exposure. Specifically, jobs which were selected for further study were ones for which heat exposure was mentioned as an environmental factor. Table 3 lists the 57 work areas in which workers were employed in the steelworkers' mortality study and the number of jobs in each of these areas identified by the manual as involving heat exposure. Out of the 7,000 jobs, there were 688 identified as involving heat exposure, which were distributed among 36 of the 57 work areas.

The jobs selected initially for field survey were the ones identified as involving heat exposure and in which 10 or more men were employed in 1953, the first year of follow-up for the cohort. This criterion was chosen so that surveyed jobs included only those for which sufficient numbers of workers were available to justify field investigation and subsequent mortality analysis.

The next step was to obtain more complete information for each job by meeting with plant personnel. The purpose of these meetings was to discuss possible discrepancies in job titles, job duties, and changes in duties or heat exposure over time. Some jobs which appeared in the list of 688 jobs no longer existed due to departmental closings, shutdowns, or job elimination. Other jobs were excluded when it was found that job duties and/or heat exposure had changed significantly over time, particularly if no adjustment was possible in the collection of field data to compensate for

these changes. It was found that many jobs now involve less heat stress than in the past, and that changes in heat stress have occurred at different times for different jobs. When heat stress changes in any job were judged to be extreme at any time prior to data collection, that job was excluded from further study. Other jobs were excluded when it was found that we could not adequately estimate heat exposure and/or energy expenditure during the survey. Extreme variability in job duties or difficulty in taking heat measurements (due to safety, for example) were the main reasons why these jobs were not surveyed.

Table 4 presents the breakdown of jobs which were not surveyed for possible heat exposure due to various reasons. It is seen that from a total of 688 jobs identified as involving heat exposure, a total of 598 jobs were eliminated from the jobs initially selected for survey due to several reasons: 439 were eliminated because of a small number of workers employed in those jobs, 77 were eliminated because these jobs did not exist at the time of the study, 25 were eliminated due to drastic changes in the jobs' exposures and 57 were eliminated since valid estimates of heat stress could not be obtained due to measurement difficulties. A survey for assessing the magnitude of heat exposure and work load was performed for the remaining 90 jobs.

Table 5 presents a list of surveyed jobs classified by work area and plant. It is seen that these 90 surveyed jobs were located in 11 work areas of the 7 plants. Also shown in this table is the number of men ever employed in these jobs prior to and including 1953. It is to be noted here that if a worker held two jobs among these 90 jobs in Table 5, he was counted twice, once for each job. Detailed information regarding work area processes and changes over time in heat exposure or work activities for these jobs is given in Appendix A.

Selection of Indoor Locations

For each job in Table 5, natural wet-bulb readings (NWB) and globe temperatures (GT) were recorded in order to calculate WBGT at each location where:

(1) the worker appeared to spend a significant percentage of his time, based on interviews or on site observation; and

(2) it appeared that heat exposure could be different than the heat exposure for other locations in the work area.

Detailed maps of work areas of interest showing assigned location numbers where measurements were taken are given in Appendix A. In locations where temperatures could vary, depending on process time, these variations were indicated by final digits of the assigned location numbers. For example, in the open hearth, for locations around the furnace a final digit of 0 represented measurements taken at times before a tap, 1 signified readings during the tap, and 2 signified measurements taken up to 45 minutes after the tap. Similar notation was used for the blast furnace area. In other mills in which steel is rolled, a last digit of 0 indicated steel was not passing, while 1 meant steel was passing.

Selection of Outdoor Locations

Readings of dry-bulb temperature (DB) and psychrometric wet-bulb temperature (PWB) were recorded at various locations outside the plants. These measurements were collected away from direct sources of plant heat. At five of the plants, outside readings were collected at one location. The other two plants are split into two major sites (each site consisting of several work areas) which are spatially separated from each other; therefore, outside readings were collected at two locations for each of these plants, one for each of the sites. A map showing the locations for all the plants where outside measurements were taken is given in Appendix A (Figure 33). A correspondence between the locations where outside measurements were taken (shown in the map) and specific work areas represented by these locations is given in Appendix A,p. A-61.

Selection of Weather Service Location

Readings of dry-bulb (DBA) and psychrometric wet-bulb (PWBA) were obtained from the National Weather Service station at the Greater Pittsburgh International Airport. The location of the Airport is indicated in the map showing outside locations in Appendix A (Figure 33).

Data Acquisition

Indoor Environmental Data

Measurements of natural wet bulb and globe temperatures were obtained using the Reuter-Stokes RSS-211 Heat Stress Monitor (5). (A copy of a photograph is included in Appendix B.) Thermistors are the temperature sensors in this instrument and its 41 mm diameter black globe is electronically corrected to give a reading which is equivalent to the standard 152 mm diameter Vernon globe to within $\pm.6^{o}C$. A series of calibrations performed in controlled laboratory environments showed that a mean correction of $-0.08^{o}C$ should be applied to the calculated WBGT. The standard error about this mean is $\pm.44^{o}C$. These tests were conducted in 12 different environments which include various combinations of 4 levels of radiant heat and 3 levels of wind. Considering the small magnitude of the correction factor it was decided that no correction was required in our WBGT data.

All field measurements of WBGT were obtained with the observer holding the instrument with the sensors positioned about 1.2 m from the floor and at least 0.5 m from the nearest individual, including the observer himself. Only about 5 minutes exposure is required for a steady reading due to the small size of the globe thermometer. The observer made certain that no significant heat sources were shielded from the temperature sensors. Frequently readings had to be taken while the worker was nearby since a reading taken at any other time would not fairly represent the heat exposure on that particular worker. Whenever possible, readings were obtained without the worker being present, but it was never feasible to obtain readings leaving the instrument unattended on a tripod.

Although not utilized in the analysis for this report, measurements of

shielded dry-bulb temperature, psychrometric wet-bulb temperature and wind speed were taken at each indoor location. A Bendix Psychron motor psychrometer was used for dry-bulb and wet-bulb. For wind speed, initially an Alnor 8500K Thermoanemometer was used. Later, a Heat Stress Monitor with a built-in thermoanemometer was utilized (also shown in Appendix B).

Outdoor Environmental Data

Outdoor readings of DB and PWB were taken at the nine locations previously mentioned, using the above instrumentation. The number and site of readings taken per day varied, depending on scheduling of work area visitations.

Data were collected as evenly as possible between the hours of 7:00 A.M. to 5:00 P.M. (Eastern Standard Time). Since a major part of the analysis involves ranking of heat levels for the jobs and nearly all workers rotate shifts (see Appendix A), evening or night time measurements were unnecessary. A copy of the form utilized to record indoor (as well as outdoor) environmental data is included in Appendix B.

Weather Service Data

On each day that outside or inside measurements were taken, hourly readings of DBA and PWBA were obtained from the National Weather Service.

Activity Data

For each job in Table 5, it was determined where persons in that job were required to work and what activities were performed, by amount of time involved.

To accomplish this aim, workers in jobs of interest were followed by one of the study employees for varying lengths of time on one or more days. On any day, if more than one worker was performing a job of interest, the worker who was followed was chosen either by study employees or by company officials. It was desirable for study purposes to attempt to follow a worker who was representative of workers in the job, at least as it exists today. No women were followed, since the steelworker cohort of 59,414 workers consisted only of males.

The number of days or amounts of time a job was followed varied according to our estimate of activity or location variability associated with that job. Some jobs were followed a total time of only several hours, when there was little variability in job routine. Other jobs were followed for several hours on several different days.

Prior to following of workers, a form was prepared for recording of the data. A copy is enclosed in Appendix B. The recorder (after writing in heading information) reported the activity being performed, the location (zone) of the worker, and the number of minutes the worker was in that zone doing that work task. The activities recorded were part of a list compiled prior to data collection. The list was included on every recording sheet. The list was inclusive of most types of general activities which might be

performed. Zone numbers were from our maps of each work area.

The minimum unit of time recorded for any activity and zone was 30 seconds. If a worker changed activity or zone before the end of 30 seconds, the recorder wrote the activity and zone appropriate when 30 seconds were completed. However, when the recorder determined that tasks were repetitive, and of less duration than 30 seconds, there were adjustments in the recording procedure. For example, if a worker performed a task for 10 seconds in each of several 30 second intervals, the worker was recorded as doing this task for 1/3 of the sum of minutes for these intervals.

METHODOLOGY AND FINDINGS

The two main sets of data to be analyzed here are (1) field data obtained in the project and (2) mortality data obtained in the steelworkers mortality study. The mortality data were already available on computer files and needed no further organization. The large volume of field data was organized and compiled for efficient utilization.

Organization and Compilation of Data

The organization and compilation of field data in this study began by coding and key punching the data and then transferring them to computer files. The data were divided into four files, containing:

File 1. Indoor environmental measurements
File 2. Outside plant environmental measurements
File 3. National Weather Service data
File 4. Activity data

A detailed description of these data collection procedures was given in the earlier section. WBGT was calculated using the formula:

$$WBGT = .7(NWB) + .3(GT)$$

All temperatures originally recorded in degrees Fahrenheit were converted to degrees Celsius. The times of recording of measurements were all converted to Eastern Standard Times. Several quality control checks made in the computer files are presented below:

(1) For indoor environmental data, plant numbers, area numbers, location numbers, dates and times of measurements were checked. All these were done by an editing program which also verified that GT and NWB were between $0^{o}C$ and $100^{o}C$ and NWB was less than or equal to GT. In cases where NWB was greater than GT, the data were checked manually and were corrected, if necessary.

(2) For outdoor environmental data, plant numbers and outdoor location numbers, dates and times of measurements were checked. Checks were also made to see whether PWB was less than or equal to DB, as well as whether PWB and DB were between $-15^{o}C$ and $100^{o}C$. These same checks were made for weather service data.

(3) For the activity data, checks were made for appropriate job numbers, plant numbers, work area numbers, location (zone) numbers, work code numbers, dates, and times.

Estimation of Heat Exposure

The first step in the analysis was to investigate the difference in the magnitude of WBGT values among different locations within a work area, so that locations similar to each other with respect to average WBGT values could be grouped together. In some locations few measurements were recorded, creating problems in seasonal breakdowns of data.

In grouping, readings, usual techniques of analysis of variance were used on the WBGT values for different locations from computer File 1 (see p. 6 for definition of files). A standard One-Way Analysis of Variance program from the Statistical Package for Social Sciences (SPSS) was employed. This analytical program computed mean WBGT values, standard deviations, confidence intervals, and the corresponding analysis of variance tables for each work area of interest within a plant.

For work areas in which there was no significant between-location F-ratio, it was decided to combine the different locations into one group. Most of the areas with furnaces were divided into two location groups, around the furnace and away from the furnace. For other work areas, decisions regarding grouping were made mainly on the basis of confidence intervals of means, spatial relationships between locations and different processing times. The groups were based on data for the entire year. It was assumed that these groups based on observations for all year are valid for individual seasons. This assumption is compatible with out extensive prior analysis of data from the opne hearth area and the data in the present study (6).

The groups and the locations within each group are shown in Figures 1-32 (Appendix A), which also contain maps of each work area. Most areas have one or two, with a maximum of three groups.

The second step in the analysis was the establishment of representative WBGT values for the different location groups (formed in step 1) for different seasons of the year and also for the whole year. It is important to note here that instead of defining seasons in the conventional way by grouping several consecutive months of the year, in the present study "seasons" were defined by ranges of outside DB. Table 6 presents the outside plant DB values (^{o}C) at different times of the day representing three seasonal subdivisions used in this study. These temperature ranges were based on dry-bulb values over a 10 year period (1961-1970) at Greater Pittsburgh International Airport. For example, if any outside temperature recorded at 10:00 A.M. was less than 4.2^{o}C, it was recorded as a winter temperature regardless of the actual calendar month when it was recorded. For readings taken somewhere in between the hours shown in the table, simple linear interpolation was used to determine season.

Since outside DB were not recorded each time an inside WBGT measurement

was obtained, the classification of the WBGT values into different seasons was not immediately possible. To circumvent this problem, models for each location where outside measurements were taken were establihsed to estimate outside plant temperatures from corresponding readings obtained from the National Weather Service. These models were of the following form:

$$DB = \beta_0 + \beta_1 \text{ (DBA)}$$

and

$$PWB = \beta_0 + \beta_1 \text{ (PWBA)}$$

The choice of these simple models was justified by the previously referenced study in the open hearth area. The standard Multiple Regression Analysis program from SPSS was employed to carry out the regression analysis.

Table 7 presents the regression equations for the estimation of outside plant DB and PWB readings from time-matched National Weather Service data. The number of observations on which the models were based and the value of coefficients of multiple determination (R^2) also are given. It was seen that in most cases the values of R^2 were quite high, indicating the adequacy of the models. Equations in Table 7 were used to form a time-matched data file of inside WBGT values and outside DB and PWB readings. Each inside WBGT value then was placed in one of the seasonal categories by comparing the corresponding time-matched outside DB temperature with different temperature ranges in Table 6. Table 8 presents the average WBGT values in different location groups by work area and plant for the three seasons defined earlier and for the entire year.

The average WBGT values for Season 1 ranged from 7.97°C to 28.85°C. The minimum value was found in the electric furnace area of Plant 2, when measurements were taken in locations away from the furnace. The maximum value was found in the billet, bloom and slab work area of Plant 5, when the readings were taken at the time of passing of steel.

For Season 2, average WBGT values ranged from 14.39°C to 30.58°C. These values were obtained in the blast furnace of Plant 6 and the coke plant of Plant 4. For Season 3, the minimum value of 29.62°C was noted in the billet, bloom and slab area of Plant 5, when steel was not passing, and the maximum value of 36.79°C was noted in the locations near the furnace of the open hearth of Plant 1.

For a given plant and work area, the all year average was obtained by averaging the average values for each season. In a relatively few instances data were not available on all three seasons for inclusion in the annual average. When this occurred, the average of Season 1 (winter) and Season 3 (summer) or the value for Season 2 (spring and fall) alone was taken to represent the average for the entire year. The average WBGT values for the entire year ranged from 15.65°C to 30.51°C. The minimum vlaue was seen in the plate mill and the maximum value was noted in the billet, bloom and slab area of Plant 5 when the readings were taken at the time of passing of steel.

It was noted that the levels of WBGT in work areas with the same title in different plants followed a similar pattern. For example, there were two open hearth areas in two plants in the study. Each of these areas were divided into two location groups, representing areas near the furnace and areas away from the furnace. The levels of WBGT were found to be similar within each location group.

For each job, average heat exposure was computed utilizing the values in Table 8. Specifically, the number of minutes each worker spent in each location was recorded on an activity data form. By placing each recorded location into the appropriate location group and using the values in Table 6, seasonal time-weighted averages of WBGT were computed for each job. For example, consider a worker employed in a job of interest in the blast furnace, Plant 1 (see Table 8). If in Season 1 he spent 20 minutes in location group 1 and 40 minutes in group 2, the average WBGT for that hour for that job equals

$$\{20(20.10) + 40(13.96)\}/60 = 16.01\ (^{o}C)$$

Estimation of Work Load

Table 9 gives estimates of the energy expenditure in kcal/minute for each activity performed by workers. Presented in this table are values from various published sources, while values in the column at the far right are estimates judged by us to be most applicable to workers in this study. By utilizing Table 9 and the entries on the activity form as to type of work and number of minutes worked, a time-weighted estimate of average total metabolism in kcal/minute was computed for each job. This estimate was based on the total time the job was followed, without regard to season. It was further assumed that seasonal variation in energy expenditure was not significant. This seemed reasonable, based upon our own data and since work patterns appeared to be most dependent on process conditions. As an example, suppose a job of interest required the worker to perform Task 11 (sitting, light arm work) for 2 minutes and Task 22 (digging) for 3 minutes. The average kcal expenditure for that job is equal to

$$\{2(2.8) + 3(8.0)\}/5 = 5.92\ (\text{kcal/minute})$$

Table 10 presents, for each surveyed job, the total number of hours workers in that job were followed for activity information, as well as our estimates of average kcal expenditure per minute and average WBGT exposure by season. The smallest number of hours any job was followed was .8 hours (Job 6016, craneman) in the annealing work area of Plant 7. The largest number of hours a job was followed was 20.1 (Job 3143, first helper in the blast furnace, Plant 2. As was mentioned previously, the total number of hours a job was followed depended largely upon our estimate of job variability. Jobs which changed little in daily routine, such as craneman jobs, were followed a smaller length of time than jobs such as those requiring men to work near furnaces in the blast furnace, open hearth, or electric furnace work areas.

Average kcal expenditure ranged from a low value of 2.02 kcal per minute

(Job 3502, charging machine operator) in the open hearth of Plant 1 to a high value of 5.12 kcal per minute (Job 3404, ladle liner) in the foundry. The job which was third highest in kcal per minute also was located in the foundry. Of the 90 jobs on the list, 49 jobs showed an estimated energy expenditure of less than 3 kcal per minute.

A particular job can exist in more than one plant. For example, in the blast furnace Jobs 3143 (first helper), 3147 (keeper) and 3199 (hot blastman) are present in all four plants with a blast furnace. For the first helper, estimated activity expenditure ranged from 3.08 kcal per minute to 3.51 kcal per minute. For the other two jobs, the ranges are from 2.80 to 3.72 and 2.27 to 2.81, respectively. Other jobs which appear more than once in Table 10 also appear to have similar average kcal values, indicating a reasonable consistency in job duties and data collection across plants.

For some jobs average WBGT values for all three seasons could not be calculated, due to lack of measurements. For example, in Season 3 (summer) average WBGT values were not calculated for 8 of the 90 surveyed jobs listed in Table 10. For the jobs for which values could be computed in Season 1, average WBGT's range from a low of 9.71°C for jobs in the foundry, Plant 6, to a high of 23.94°C for Job 1750 (engineer) in power and fuel, Plant 4. The range in Season 2 is from 14.99°C in power and fuel, Plant 5 to 30.58°C for Job 2235 (quenching car operator) in the coke plant, Plant 4. The lowest average WBGT in Season 3 is 23.23°C for Job 4153 (stamper) in billet, bloom and slab, Plant 5, while the highest value is 34.35°C for Job 5707 (salt man) in the plate mill, Plant 1. The average WBGT's for the whole year were computed in the same manner that the yearly averages in Table 8 were computed. Jobs which appear in more than one plant of Table 10 also have similar average WBGT values, in addition to having similar average kcal per minute.

It may be noted that some jobs within a particular plant and work area in Table 10 have equal average WBGT. This will be true in all cases in which there is only one location group shown in Table 8 for the plant and work area. An example is for jobs in the annealing area of Plant 7.

Analysis of Mortality

Methodology

Since this is essentially the first study to evaluate the relationship of mortality to long-term heat exposures in industry, the analysis in this report has been designed to present an overview of mortality from many causes in relationship to environmental and metabolic heat load. The results should be regarded as providing the basis for developing further specific hypotheses, if indicated, which would then be explored in-depth either by utilizing this data set or by designing additional studies of appropriate focus. The statistical techniques employed for mortality analysis have been used in previous reports dealing with the long-term mortality of steelworkers, but will be summarized here in order to facilitate interpretation of the tables.

As it has been mentioned earlier, the mortality data come from a longitidinal study of mortality in the steel industry conducted by the Department of Biostatistics, University of Pittsburgh. For each of the approximately 59,000 men employed in 1953 at the seven steel plants information obtained from plant personnel records included a complete work history from the time of initial employment with the firm through 1970, birthdate, and rece, as well as information needed for follow-up of individuals who had left the plant. For all decedents, copies of death certificates were obtained from state vital statistics offices and were coded according to the Seventh Revision of the International List.

In the beginning of the study, jobs were identified for which heat exposure was mentioned in the Job Description and Classification Manual. These jobs were referred to as jobs presumed to involve heat exposure. Jobs actually surveyed for the level of heat exposure and physical work load were a subset of jobs presumed to involve heat exposure and were referred to as jobs surveyed. The control group was selected to be composed of workers who were never employed through 1953 in any of the work areas in which jobs were surveyed. For the first phase of mortality analysis, the mortality experience of workers employed in jobs presumed to have heat exposure and in jobs surveyed was compared. For subsequent phases of mortality analysis, surveyed jobs were divided into different groups according to levels of environmental and metabolic heat exposure. The mortality experiences of men employed in jobs in these different groups were compared by length of employment.

Mortality risks were analyzed by computing relative risks for selected causes of death. A brief description of the calculation of relative risk for a cause of death for workers in a group of interest is given below. Workers in a group of interest and the control group were stratified by race, age at entry to the steelworkers' study (1953) and the following calendar periods of mortality follow-up: 1953-1957, 1958-1962, 1963-1967, 1968-1970. The expected number of deaths from a selected cause of death was calculated for each of these strata specified above, under the assumption that workers in the group of interest and control group have the same death rate within each stratum. The total expected number of deaths is the sum of the specific rates for the total workers in the stratum multiplied by the number of group of interest workers at risk in the stratum. The relative risk is a weighted average of the observed and expected number of deaths for each stratum, where the weights are approximately proportional to the precision within each stratum. To test whether the relative risks differ significantly from one, a summary chi-square with one degree of freedom has been calculated (15, 16). Computational details regarding the relative risk and the summary chi-square are given in Appendix C.

It should be remembered that whenever a large number of significance tests are performed a certain number of tests may be significant by chance alone. In addition, the problem of multiple comparisons and testing at specific significance level arises. Therefore, significance levels should not be overstressed, but rather serve as a guide, with close examination of the consistency of significant findings.

Findings

(1) Mortality of Jobs Presumed to Involve Heat Exposure vs. Jobs Surveyed

Since jobs actually surveyed were a subset of jobs for which heat exposure was mentioned it is of interest to compare mortality experience for workers in jobs surveyed and jobs presumed to involve heat exposure. Table 11 presents a list of causes of death which are presented in this study with corresponding ICD codes (17). The relative risks for each of these causes for workers ever employed through 1953 are presented in Table 12. The relative risk for all causes was found to be significantly low for jobs surveyed and slightly (but not significantly) low for jobs presumed to involve heat exposure when compared with the control group. In the surveyed job group, significantly low risks are found for cardiovascular-renal disease, primarily attributable to lower rates for arteriosclerotic heart disease. Mortality for most of the causes of death listed appears slightly lower in the surveyed group, with the relative risks for jobs with presumed heat exposure tending to be closer to one than the risks for the surveyed jobs.

(2) Classification of Workers in Surveyed Jobs by WBGT and Work Load

In order to investigate mortality patterns in relation to heat exposure, work load, and length of exposure, the cohort of workers in surveyed jobs was first divided into subcohorts according to the values of the first two variables, viz average WBGT and average kcal/minute. This was accomplished in the following manner. For each season two categories of WBGT values were chosen, based on the median values of the distribution of WBGT values within that season. Two categories of kcal/minute values also were chosen, based on the median value of the corresponding distribution. (As the work-load does not change by season for a job, there is only one distribution of kcal/minute, representing all three seasons.) The jobs were then cross-classified by these two variables for each season separately. Although WBGT values were not available for all the jobs in all the seasons (see Table 10), the distributions of jobs for three different seasons were found to be quite similar. Since heat stress is greatest in summer months, it was decided to utilize the subdividions formed for Season 3 in the analysis of mortality. The distribution of the 82 jobs for which WBGT values were available for Season 3 is presented in Table 13, in the form of a 2 x 2 table. The four cells of this table are termed category I, category II, category III and category IV. For example, category I represents jobs with average WBGT values $\leq 26.33^{o}C$ and average kcal/minute values ≤ 2.90.

The mortality experiences of workers in each category were compared to mortality in the control group. As some workers were employed in several jobs belonging to different categories, a priority scheme described below was used to classify a worker into only one of the four categories given in Table 13. Category IV was given the highest priority as it involved jobs where heat and energy expenditure were both at their highest levels. Category III was given the next highest priority and category II was given the third highest priority. Category I was given the lowest priority.

For each worker, each of his surveyed jobs was placed into one of the four categories of Table 13, and for mortality analysis the worker was considered only in the category of the highest priority in which he held at least one surveyed job. For example, suppose a worker was employed in two jobs, one with WBGT equal to 28°C and an energy expenditure of 2.6 kcal/minute (category III) and the other with a WBGT of 20°C and energy expenditure equal to 3 kcal/minute (category II). This worker was classified in category III.

Tables 14 to 21 present relative risks for jobs from all work areas in each of the four categories for all causes and the 31 selected causes of death listed in Table 11. The first row of each of these mortality tables presents mortality experience for workers who ever worked in a surveyed job through 1953. These workers are referred to as the "ever worked" group; sucessive rows present the mortality for the workers stratified by length of employment (also referred to in this report and tables as length of exposure). In these tables, a worker's total length of employment is equal to the sum of the lengths of employment in all jobs belonging to the worker's determined category, regardless of work area. In a separate analysis for specific work areas, each worker was placed in the same category as in the analysis for all work areas combined. His length of employment in a particular work area is equal to his total length of employment in that work area in surveyed jobs in the determined category. It should be noted that as a worker may have been employed in several work areas, groups of workers representing the different work areas are not mutually exclusive.

Table 14 shows that relative risks for all causes of death generally were lower for workers in jobs surveyed than for the control group of workers. For the ever worked group, risks were significantly low for category IV. For all cancers, although no significant risks are shown in Table 15, increased risk was noted for workers in the coke plant. This higher risk occurred in category IV. (No coke plant jobs are classified in category I; thus, a relative risk could not be computed for coke plant workers exposed to that level of heat and work.) The increased risk in the coke plant was due primarily to a significant risk of cancer of the lungs, bronchus, and trachea.

A significantly high relative risk from digestive and peritoneal cancer was seen for workers ever employed or employed 15 or more years in category III (Table 16). An increased risk for this disease was observed for workers ever employed in category III of the open hearth. A significantly low risk was observed for cancers of lymphatic and hematopoietic tissues for workers in category I (Table 17).

Due to the physiological effect of heat on the heart and circulatory system, mortality from cardiovascular-renal disease (CVR) was of particular interest. Table 18 shows that for all work areas, relative risks were significantly low for workers in the ever worked group in categories III and IV, indicating a possible relationship between decreased mortality and environmental heat stress. When the mortality experience was examined by length of exposure, a significantly high risk was noted among workers with less than 6 months exposure in category II and higher than expected

risks in the other three categories. It should be noted that the mortality risks tended to decrease with increased length of exposure.

When mortality from CVR was examined for individual work areas, a significantly low relative risk was noted among workers who ever worked in the blast furnace in category III. A significant deficit in mortality was also noted in the workers having 10-14 years of exposure in category IV in this area. Low risks also were observed for workers in the coke plant and open hearth for the ever worked group in category IV.

When CVR was subdivided, mortality risks of dying from arteriosclerotic heart disease was found to be significantly low among men who ever worked in categories III and IV (Table 19). Significantly high risks were seen for workers in category I with 5-9 years of exposure, and a high risk was found in category II among workers with 10-14 years of exposure. Significantly low risks for this disease were noted for men who ever worked in a job in category IV.

Another finding was an increased risk of death from nonmalignant digestive disease among workers surveyed. The effect was most evident in categories III and IV where significantly high risks were found for workers with 15 or more years of experience (Table 20). The risks for other nonmalignant digestive disease (excluding cirrhosis of the liver) were observed to be significantly high in category IV for the ever worked group and the group with 15 or more years of exposure (Table 21). Investigation with respect to specific work areas suggested that most of the excess cases were in the open hearth.

(3) Classification of Workers in Surveyed Jobs by WBGT Only

The above analysis suggested a relationship between environmental heat exposure and mortality for some causes of death. No work load effect or any interactive effect between the two components of heat stress were apparent, except possibly for nonmalignant digestive disease. Therefore, it is of interest to investigate the mortality patterns by different levels of environmental heat exposure only. Accordingly, the four new categories were defined from the WBGT values only, based on the quartiles of the distribution of WBGT values for Season 3, which are, hereafter, referred to as categories I-IV. Table 22 lists the 82 jobs according to the redefined categories.

The mortality experience of workers in each of these four groups of jobs was compared to the mortality experience of the workers in the control group for all work areas and individual work areas. As some workers held more than one surveyed job, a priority scheme was used to classify a worker into only one category, as before. Highest priority was given to category IV, next highest to category III, third highest to category II and the lowest priority was given to category I. Each worker was placed into the category of highest priority in which he held at least one surveyed job. The classification of workers into different work areas and determination of length of exposure followed the same method described earlier.

Table 23 shows that relative risks for all causes of death were generally lower for workers in jobs surveyed than for the control group of workers. Significantly low risks were seen in categories II and III.

For all cancers, although no significant risks were noted for all work areas (Table 24), significantly high risk was found for workers in jobs in the coke plant, in category IV. In category III, the risk, although not significant, was found to be greater than one. As previously noted, the high risks of death from lung cancer appear to be the explanation for this finding. A significantly high risk from genito-urinary cancer was noted among workers in the ever worked group in category IV (Table 25). The high risk, however, did not appear to concentrate in any specific work area.

Table 26 shows that the relative risks for cardiovascular-renal disease was significantly low for workers in categories III and IV and lower than one (although not significantly) in category I. When the mortality experiences were examined by length of exposure, higher risks were noticed among workers with short exposure time. When the mortality patterns were examined by work area, significantly low risks were noted for workers in the open hearth, blast furnace and coke plant areas.

Mortality risks for arteriosclerotic heart disease were significantly low for workers in the ever worked group in categories III and IV (Table 27) with the risks appearing to decrease with increasing length of exposure. Detailed investigation shows the opne hearth area to have significantly low mortality in category III for this disease.

The previously noted increased risk of death from nonmalignant digestive disease was found to be greatest in category IV, the highest level of WBGT (Tables 28, 29).

(4) Classification of Workers in Surveyed Jobs by the Threshold Limit Value (TLV) of the ACGIH

In this analysis, environmental and metabolic estimates of heat stress for each job was compared to the heat stress TLV of the American Conference of Governmental Industrial Hygienists (Figure 1) (18, 19).

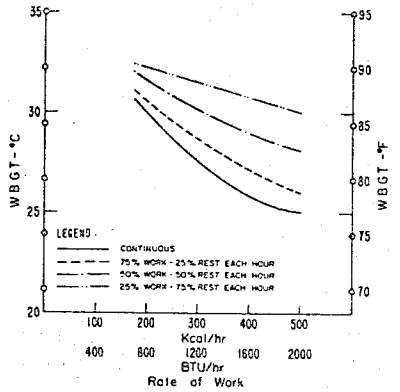

Figure 1 — Permissible Heat Exposure Threshold Limit Value

For each job, the estimate of average WBGT for Season 3 and average kcal/hour were compared to the lower curve of the ACGIH TLV. By this criterion, 7 jobs were found to be above the exposure limits and 75 jobs were found to be below the limits. Table 30 lists the 82 jobs in each of these two categories. For classifying workers into only one of the two categories, jobs above the TLB were given priority over jobs below the TLV. The classification ow workers into different work areas and determination of length of exposure were done as before.

The mortality experience of workers in each of these two categories of jobs was compared to the mortality experience of the workers in the control group for all work areas and individual work areas. Table 31 shows that the relative risk for all causes of death was significantly low for the ever worked group, for workers in jobs which were below the standard. Except for the group with less than 6 months exposure, risks were consistently low. For the jobs above the TLV, low relative risks, although not statistically significant, were noted for the ever worked group and men who worked less than 5 years.

A significantly low risk was found for cancers of lymphatic and hematopoietic tissues for workers in jobs below the proposed standard (Table 32).

Significantly low risks from cardiovascular-renal disease were noticed among workers in both groups (Table 33). Workers in jobs below the standard with less than 6 months exposure showed a significant excess mortality. For arteriosclerotic heart disease, significantly low risks were shown for the ever worked group and for workers with 15 or more years experience among workers in jobs below the TLV (Table 34). Risks lower than one were noted for workers in jobs above the standard, though the risks were not significant. Significantly high risks were found for other nonmalignant digestive disease (excluding cirrhosis of liver) for workers who ever worked in jobs above the TLV and in jobs below the TLV for men with 15 or more years of work experience (Table 35).

DISCUSSION

When jobs were divided according to two levels of environmental heat, decreased mortality from cardiovascular disease was found for workers who were employed in jobs at the higher of the levels. However, whne these two categories of environmental heat were further subdivided into two categories each, no difference in mortality was observed for the men employed in jobs in the two hottest categories. Thus, lower risks of death from cardiovascular disease could be associated only with exposure above a certain level of WBGT, with no consistent relationship above that value. Work load did not appear to be an independent contributing factor in the risk of cardiovascular disease. Following categorization of jobs by the ACGIH TLV for heat stress, significantly low risks were observed for workers in jobs both above and below the TLV, with the risks somewhat lower for workers above the TLV.

Although a finding of decreased risk of mortality from cardiovascular disease differs from results suggested by several articles, it is not clear

what factors other than heat enter into these findings (20, 21). Further, the earlier studies are based on cross-sectional rather than longitudinal data.

Significantly high risks for death from cardiovascular disease and all causes combined were noted for men with less than 6 months of exposure. These higher risks may be indicative of a relationship between inability to work in jobs involving heat stress and health. This selection for health may at least partially explain the results for mortality from cardiovascular disease. Workers who are less fit leave the job after varying lengths of exposure, thus resulting in a downward trend in mortality for workers who remain on the job. Although there is no way to compensate completely for the selection factors which enter into initial job placement and job morbidity for jobs involving heat stress, it should be noted that there is no evidence for any deleterious effect of heat exposures for the cardiovascular system even when one compares mortality of workers with longest term exposures. Although the issue of longevity of workers exposed to heat cannot be evaluated directly, since not all workers were followed to death (hence, average life expectancy cannot be calculated), the low relative risks would imply on overall favorable survival pattern among workers studied here.

An increased risk of death from nonmalignant digestive diseases among workers employed in surveyed jobs was observed. Workers employed in jobs at the highest levels of WBGT were significantly affected. It was also found that workers at greatest risk were the ones who were employed a longer period of time. When jobs were subdivided by the TLV, however, higher risks for this disease (excluding cirrhosis of liver) were found for workers employed in jobs above and below the TLV, with the greatest excess occurring for the workers above the TLV. It was found that workers who died of nonmalignant digestive disease, excluding cirrhosis, lived an average of 12.6 years after leaving their last surveyed job. Thus, in most cases death does not appear to be due to aggravation of a pre-existing condition by exposure to heat. It is not known, however, how many of the men whose death was caused by digestive illness prior to or during employment in a hot job. We cannot, at this time, suggest specific biological mechanisms to explain why heat stress should cause a higher mortality from digestive disorders.

Increased mortality risks were noted for surveyed coke plant workers for all cancers and cancer of the lungs, bronchus, and trachea. These higher risks occurred at the higher levels of WBGT. High risks for these disease categories have been noted elsewhere for all coke oven workers with a direct relationship observed to level of coal tar pitch volatiles (22, 25). It is unclear whether heat is a contributory factor to this increased risk.

The possibility that intense, short periods of heat stress exposure have important health implications should be considered. Workers placed in the categories of highest average heat stress in this report included most surveyed workers who are exposed to these intense periods of exposure. Further analyses should be done comparing workers with intermittent intense heat stress to workers with more continuous heat exposure. Also, since mortality data cannot be used for diseases which are generally not fatal,

no inferences can be drawn from this study relative to skin cancer or other morbidity conditions which might be of interest.

SUMMARY AND RECOMMENDATIONS

This study examines the possible relationships between heat stress and cause-specific mortality in a large cohort of steelworkers. Jobs which involved heat exposure were identified prior to field study and were surveyed for environmental heat exposure and work load. Different categories of heat stress were formed based on the values of environmental heat exposure and work load and surveyed jobs were subdivided into these categories. The mortality experience of workers who were employed in jobs in each of these categories were compared to the mortality experience of a control group of workers, which consisted of men who were never employed in any of the work areas in which jobs were surveyed. Mortality was compared within each category of heat stress by different lengths of employment. The important observations are:

(1) workers in jobs involving higher environmental heat showed decreased risks of death from cardiovascular disease and the risks decreased with increasing length of exposure. Work load did not appear to be an independent contributory factor;

(2) workers with less than 6 months exposure in surveyed jobs showed higher risks of death from cardiovascular diseases. These higher risks may be indicative of a relationship between inability to work in jobs involving heat stress and health; and

(3) increased risk of mortality from nonmalignant digestive disease was found for workers employed in surveyed jobs placed in higher environmental heat categories. After excluding cirrhosis of the liver from consideration, high risk was noted only at the highest category of heat stress.

It would be possible using data obtained in this study to analyze mortality of workers categorized by other indices of heat stress, such as the Belding and Hatch Heat Stress Index (HSI). The mortality patterns obtained by utilizing these other indices could be compared to results of categorization by WBGT.

As mentioned in the discussion, a future study or additional analysis of the current data also is needed to investigate possible effects of intermittent, intense periods of heat stress on mortality. By establishing some criterion of "peak" exposures, workers could be classified by the frequency or duration of such exposures and mortality patterns for these groups of workers could be investigated. The findings relative to mortality from digestive disorders should be evaluated further by means of a prevalence survey of workers employed in hot jobs compared to an appropriate group of workers not exposed to heat. If the results of the survey are consistent with an excess morbidity from digestive diseases more in-depth investigations should be designed to evaluate specific etiologic hypotheses.

A comparison of the mortality of heat exposed workers with that of the general population would be of interest since the control group consisted of workers employed in the same plants and may have a lower immortality risk in most diseases than the general population.

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Table 1

Sample Job Evaluation in Job Description and Classification Manual[4]

Standard Code - AA 02020 Standard Title - Lidman

SPECIMEN EXAMPLE
OF
JOB DESCRIPTION AND CLASSIFICATION
(Represents an Actual Case in Fact)

Page No. 66
File Code AD 0330 Z-06

Department Coke Plant Job Title (Std.) Lidman
Sub Division Batteries Job Title (Plant) Lidman
January 16, 1946 JOB DESCRIPTION

Primary Function:

To pull lids and otherwise assist in the preparation of the ovens for pushing and charging.

TOOLS AND EQUIPMENT:

Bars, shovel, broom, protective clothing, etc.

MATERIALS:

Coke, coal, etc.

SOURCE OF SUPERVISION:

Battery Foreman issues verbal instructions and Gas Tender assigns and directs work.

DIRECTION EXERCISED:

None.

WORKING PROCEDURE:

Mixes luting mud with water to form a sealing mixture to seal charging lids as required.
Works in close cooperation with Gas Tender.
Removes lids from ovens to be pushed; replaces lids on ovens that have been charged. Uses long handled lidding broom with wooden handle and steel bristles to sweep coal spillage into the oven charged before replacing lids. Also uses heavy lid hook and long handle shovel.
Wears heavy clothing, shoes, leggings and lidding mask when necessary.
Occasionally cleans charging holes with bar and checks holes to see that they are clean.

Standard Code - AA 02020 Standard Title - Lidman

JOB CLASSIFICATION

Job Title (Plant): Lidman File Code AD 0330 Z-06

Factor — Reason for Classification	Code	Classification
1. Pre-Employment Training. This job requires the mentality to learn to: Remove and replace lids on coke ovens.	A	Base
2. Employment Training and Experience. This job requires experience on this and related work of Up to and including 2 months of continuous progress to become proficient.	A	Base
3. Mental Skill Perform simple repetitive manual tasks.	A	Base
4. Manual Skill Use bars and other rough tools.	A	Base
5. Responsibility for Material — Estimated Cost: Performs task where damage is not likely. Possible loss of gas by careless sealing of lids. — $50 or Under	A	Base
6. Responsibility for Tools and Equipment Damage to rough hand tools is unlikely.	A	Base
7. Responsibility for Operations Performs simple routine work requiring some coordination with others.	B	.5
8. Responsibility for Safety of Others Likelihood of injury to others is low. May put lids on too soon and cause burns to others.	A	Base
9. Mental Effort Minimum mental application required to perform simple routine work.	A	Base
10. Physical Effort Moderate physical exertion to use bars to pull lids, large brooms to sweep spillage, etc.	C	.8
* 11. Surroundings Exposed to extreme heat, dust and fumes. Works outside in all weather.	E	3.0
12. Hazard Exposed to burns from hot materials and gas flashes. May be struck by larry car.	C	.8
Job Class 5	Total	5.1

*See Table 2 for definitions of codes and numerical classifications

Table 2

Definitions of Codes and Numerical Classifications for Work Surroundings in Job Description and Classification Manual[4]

Factor 11 - Surroundings

Code	Work Requires Exposure to:	Numerical Classification
A.	Inside machine shop or average factory type of building. Slightly dirty, noisy and not uniformly heated.	Base
B.	Heat in summer due to proximity to furnaces or hot materials. Inside and outside conditions but not required to remain out in extreme weather. Outside weather conditions but protected part of time by roofs, pulpits or cabs. Continually dirty or greasy work, or exposure to wetness and some fumes and smoke.	.4
C.	All weather conditions where weather is severe. Considerable wetness, acids, fumes, dust, or glare necessitating the wearing of protective clothing or devices. Extreme conditions of dirt where man becomes covered with obnoxious dirt such as tar, paint, etc. Extreme heat for intervals but not for extended periods. Intense noise for extended periods.	.8
D.	Extreme heat of intense degree and for considerable time.	1.6
E.	Extreme heat approaching the point of endurance where relief from surroundings at regular intervals is a necessity.	3.0

Table 3

Work Areas in Prior Steelworker Mortality Study and Number of Jobs Identified by Job Description and Classification Manual[4] as Involving Heat Exposure

Work Area	No. Jobs Involving Heat Exposure
General Administrative and Clerical	0
General Technical	4
Coke Plant	22
Blast Furnace	15
Open Hearth	33
Bessemer Converter	59
Electric Furnace	5
Foundry	17
Heat Treating and Forging	0
Billet, Bloom, and Slab Mills	58
Soaking Pits	10
Merchant Mills	38
Plate Mill	32
Axle Mills	55
General Finishing and Shipping	16
Hot Strip Mill	24
Rail Mill Rolling	19
Rail Mill Finishing	11
Steel Yards	0
Structural Mill	3
Annealing Normalizing	20
Batch Pickling and Sheet Dryers	0
Coating	11
Cold Reducing Mills	0
Continuous Pickling and Electric Cleaning	4

Table 3 (Continued)

Work Areas	No. Jobs Involving Heat Exposure
Flying Shears and Slitters	0
Hot Pack Mills	12
Hot Strip Rolling	27
Sheet Finishing and Shipping	0
Stainless Annealing, Pickling, and Processing	0
Temper Passing and Cold Rolling	0
Tin Finishing and Shipping	4
General Labor	0
Janitors	0
Mason Department	4
Blacksmith Shop	14
Carpenter Shop	0
Electric Maintenance Assigned	2
Electric Shop	0
Garage	2
Locomotive and Car Repair	0
Machine Shop	1
Maintenance NOS	0
Mechanical Maintenance Assigned	3
Paint Shop	0
Pattern Shop	0
Pipe Shop	2
Riggers and Structural	0
Roll Shop	1
Weld Shop	4
All Other Work Areas	60
General Receiving and Stores	0
Plant Protection	0

Table 3 (Continued)

Work Area	No. Jobs Involving Heat Exposure
Power and Fuel	14
Transportation and Yard	4
Tube Mills	78
River or Marine Ways	0
All Work Areas	688

Table 4

Selection of Jobs for Field Study From Jobs Identified by Job Description and Classification Manual[4] as Involving Heat Exposure

Groups of Jobs	No. Jobs	
Jobs Involving Heat Exposure, According to Job Description and Classification Manual	688	
Jobs Not Surveyed	598	
Jobs Eliminated Because Less Than 10 Workers Employed in 1953		439
Jobs Which No Longer Exist, Due to Departmental Shutdowns, Closings or Job Elimination		77
Jobs for Which Environmental Heat Exposure or Activity has Changed Markedly		25
Jobs Not Evaluated Due to Variability in Job Duties, Difficulty in Taking Heat Measurements, etc.		57
Jobs Surveyed	90	

Table 5

Surveyed Jobs and Number of Men Ever Employed in These Jobs Through 1953, by Work Area and Plant

Work Area	Work Area No.	Plant No.	Job Title	Job No.*	No. Workers Ever Employed Thru 1953
Annealing	21	7	Annealer	7181	10
			Assistant Annealer	7182	20
			Craneman	6016	30
			Hooker	6015	49
Billet, Bloom, and Slab Mills	10	1	Craneman	4036	50
		2	Stamper	4153	94
		5	Stamper	4153	66
Blast Furnace	4	1	First Helper	3143	133
			Hot Blastman	3199	11
			Keeper	3147	12
		2	First Helper	3143	135
			Hot Blastman	3199	89
			Keeper	3147	31
		5	Cinder Snapper	3107	79
			First Helper	3143	116
			Hot Blastman	3199	40
			Keeper	3147	36
		6	Cinder Snapper	3107	119
			First Helper	3143	126
			Hot Blastman	3199	53
			Keeper	3147	34
Coke Plant	3	2	Heater	2304	17
			Heater Helper	2140	36
			Lidman	2170	69

Table 5 (Continued)

Work Area	Work Area No.	Plant No.	Job Title	Job No.*	No. Workers Ever Employed Thru 1953
		4	Door Machine Operator	2120	92
			Heater	2304	57
			Heater Helper	2140	111
			Lidman	2170	105
			Quenching Car Operator	2235	81
Electric Furnace	7	3	First Helper	3348	11
			Second Helper	3342	12
			Third Helper	3343	50
		5	First Helper	3348	22
			Second Helper	3342	42
			Third Helper	3343	50
Foundry	8	6	Chipper	3403	141
			Ladle Liner	3434	25
			First Closer	3992	179
			Second Closer	3994	42
			Closer Helper	3993	145
			Craneman	3419	69
Hot Strip Rolling	28	2	Slab Shearman	6481	27
		7	Coil Bender	6423	77
Mercant Mill	12	4	Heater	5551	16
			Heater Helper	5553	40
			Leverman	5535	73
			Guide Setter	5543	35
		5	Finisher	5580	30
			Heater	5551	15
			Rougher	5601	36

Table 5 (Continued)

Work Area	Work Area No.	Plant No.	Job Title	Job No.*	No. Workers Ever Employed Thru 1953
Open Hearth	5	1	Charging Machine Operator	3502	633
			Hot Metal Craneman	3505	67
			Ladle Craneman	3507	58
			Mixer Operator	3559	15
			First Helper	3360	171
			Second Helper	3583	267
			Third Helper	3365	291
			First Steel Pourer	3361	29
			Platform Man	3364	33
		2	Charging Machine Operator	3502	66
			Hot Metal Craneman	3505	31
			Hot Top Liner	3539	17
			Ladle Craneman	3507	24
			Mixing Craneman	3509	24
			Stripper Craneman	3519	17
			First Helper	3360	125
			Second Helper	3583	228
			Third Helper	3365	259
			First Steel Pourer	3361	23
Plate Mill	13	1	Charger	5649	54
			Heater	5669	27
			Hooker	5673	71
			Layout Man	5656	18
			Marker	5642	33
			Plate Shearman	5719	41
			Salt Man	5707	40
			Scrapman	5709	81
			Stamper	5659	65

Table 5 (Continued)

Work Area	Work Area No.	Plant No.	Job Title	Job No.*	No. Workers Ever Employed Thru 1953
Power and Fuel	54	1	Fireman	1707	22
			Oiler	1747	39
			Water Tender	1754	32
		4	Engineer	1750	18
		5	Boiler Cleaner	1704	35
			Flue Cleaner	1725	136
			Water Tender	1754	21
			Boiler Repairman	1702	39
		6	Engineer	1750	48
			Fireman	1707	71
			Pump Tender	1752	49
			Water Tender	1754	26

*Job numbers assigned in earlier steelworkers' study

Table 6

Outside DB Temperatures (°C) Defining Seasons

Season	Time			
	7:00 A. M.	10:00 A. M.	1:00 P. M.	4:00 P. M.
Winter (Season 1)	≤1.2	≤4.2	≤6.9	≤7.4
Spring & Fall (Season 2)	1.3 - 11.9	4.3 - 16.9	7.0 - 19.8	7.5 - 20.2
Summer (Season 3)	≥12.0	≥17.0	≥19.9	≥20.3

Table 7

Regression Equations to Estimate Outside Plant DB (°C) and PWB (°C) Readings From Airport Readings

Plant No.	Outside Location No.	N	Regression Equation	R^2
1	1	104	DB = 4.43 + .88 (DBA)	.94
		104	PWB = 5.10 + .77 (PWBA)	.84
	2	81	DB = 4.78 + .88 (DBA)	.93
		81	PWB = 4.82 + .80 (PWBA)	.87
2	1	95	DB = 4.53 + .87 (DBA)	.94
		95	PWB = 4.31 + .82 (PWBA)	.90
	2	106	DB = 4.28 + .92 (DBA)	.95
		106	PWB = 4.53 + .84 (PWBA)	.89
3	1	63	DB = 3.05 + 1.00 (DBA)	.98
		63	PWB = 2.58 + 1.02 (PWBA)	.98
4	1	103	DB = 4.12 + .95 (DBA)	.95
		103	PWB = 4.27 + .83 (PWBA)	.85
5	1	108	DB = 4.10 + .93 (DBA)	.95
		108	PWB = 4.92 + .78 (PWBA)	.80
6	1	116	DB = 3.83 + .96 (DBA)	.95
		116	PWB = 4.06 + .90 (PWBA)	.90
7	1	72	DB = 3.34 + .97 (DBA)	.96
		72	PWB = 3.86 + .91 (PWBA)	.91

Table 8

Average WBGT Values (°C), by Work Area, Plant, Location Group, and Season

Work Area	Plant No.	Location Group No.	Season 1		Season 2		Season 3		All Year	
			N	Average WBGT	N	Average WBGT	N	Average WBGT	N	Average WBGT
Annealing	7	1	27	17.24	7	20.97	34	26.85	68	21.51
Billet, Bloom, and Slab Mills	1	1	--	--	4	18.05	5	27.04	9	18.05
	2	1	--	--	12	18.64		--	12	18.64
	5	1	4	28.85	10	29.11	4	34.97	18	30.51
		2	3	16.53	15	20.15	6	20.62	24	19.36
Blast Furnace	1	1	9	20.10	31	27.01	17	31.21	57	26.33
		2	13	13.96	40	20.10	28	25.65	81	19.95
	2	1	6	16.45	25	24.23	31	30.89	62	27.06
		2	8	12.43	50	17.87	73	27.52	131	22.79
	5	1	11	22.56	13	28.86	--	--	24	28.86
		2	19	9.10	42	20.03	--	--	61	20.03
	6	1	12	7.99	45	17.81	40	27.92	97	17.88
		2	16	11.02	56	14.39	49	24.46	121	16.07
Coke Plant	2	1	3	15.33	14	16.04	21	24.37	38	17.95
		2	3	14.83	11	24.94	20	31.96	34	24.17
	4	1	9	12.92	8	20.85	27	22.55	44	19.29
		2	11	15.51	21	30.58	35	29.34	67	26.50

Table 8 (Continued)

Work Area	Plant No.	Location Group No.	Season 1		Season 2		Season 3		All Year	
			N	Average WBGT	N	Average WBGT	N	Average WBGT	N	Average WBGT
Electric Furnace	3	1	32	17.59	31	20.98	68	29.91	131	22.37
		2	29	7.97	55	16.53	107	24.48	191	16.38
	5	1	--	--	15	26.98	--	--	15	26.98
		2	--	--	32	22.55	--	--	32	22.55
Foundry	6	1	37	9.71	32	17.17	53	23.61	122	16.92
Hot Strip Rolling	2	1	--	--	13	21.39	26	26.19	39	21.39
	7	1	10	15.51	--	--	19	24.10	29	19.81
Merchant Mill	4	1	--	--	30	19.56	11	25.00	41	19.56
	5	1	12	13.55	9	23.93	27	26.09	48	21.88
		2	5	24.04	5	25.56	12	29.51	22	26.17
Open Hearth	1	1	28	17.13	65	28.56	37	36.79	130	27.76
		2	19	13.58	42	19.41	28	25.93	89	19.58
	2	1	35	20.68	56	28.39	25	32.66	116	27.53
		2	22	11.23	52	20.34	28	24.83	102	19.19
Plate Mill	1	1	--	--	25	25.04	32	31.88	57	25.04
		2	--	--	17	15.65	27	26.07	44	15.65
		3	--	--	5	27.28	11	34.85	16	27.28

Table 8 (Continued)

Work Area	Plant No.	Location Group No.	Season 1		Season 2		Season 3		All Year	
			N	Average WBGT	N	Average WBGT	N	Average WBGT	N	Average WBGT
Power and Fuel	1	1	7	18.49	25	23.64	20	29.23	52	23.75
	4	1	--	--	16	17.98	7	23.94	23	17.98
		2	--	--	34	20.45	10	25.41	44	20.45
	5	1	18	10.72	14	14.99	22	24.36	54	16.27
	6	1	55	15.39	65	17.19	53	26.04	173	18.95
		2	17	23.18	26	27.32	9	33.62	52	27.86
		3	4	20.63	22	23.19	7	27.60	33	23.65

-- Indicates no measurements taken

Table 9

Values of Human Energy Expenditure Corresponding to Worker Activities

(kcal/min per 70 kg man)

Activity	Ergonomics Guide (7)	Minard (8)	Purdue (9)	Henschel (10)	Passmore & Durnin (11)	Lehmann (12)	Goldman (13,14)	Present Study Estimate
Sitting								
10. At Rest	1.5	1.5	1.5	1.6	1.4	1.6		1.5
11. Light Arm Work	-	2.1	3.0	2.7		2.75		2.8
12. Moderate Arm Work	-	-	3.7	3.3		3.2		3.2
13. Heavy Arm Work	-	-	4.0	-		3.5		3.5
Standing								
20. At Rest	1.9	1.8	1.8	1.7	1.7	2.1		2.0
21. Lifting	-	3.2[i]	4.0[ii]	-				3.7
22. Digging	-	-	7.5	7.3	8.0	8.0		8.0
23. Shoveling	-	6.0	6.8	7.7	6.0	7.8		7.0
24. Light Arm Work	-	3.3	3.3	- 2.9		2.8-3.1		3.0
25. Moderate Arm Work	-	4.2	3.8	3.3		3.5		4.0
26. Heavy Arm Work	-	-	4.3	3.8		4.0		4.5
27. Light Arm & Trunk Work	-	-	5.3	4.7		4.8-5.2		5.0
28. Moderate Arm & Trunk Work	-	-	6.8	6.1		6.9		6.5
29. Heavy Arm & Trunk Work	-	9.4	8.8	8.8		8.6		9.0
Walking								
30. Slowly	3.6[iii]	3.8	3.3[iii]	3.5	3.8-4.5	3.5	4.8	4.5
31. Rapidly	4.9[iv]	4.6	4.7[iv]	4.4	6.0		7.9	7.0
32. Moving Empty Wheelbarrow						4.0-7.0	6.5[v]	6.5
33. Moving Full Wheelbarrow								7.5
34. Carrying with One Hand	-	4.7	4.8[vi]	-	6.0	4.0	6.0	5.0
35. Carrying with Two Hands								6.0
36. Light Arm Work	-	-	4.8	5.0		4.5	6.0	5.0
37. Moderate Arm Work	4.5		5.3	5.5		5.2	7.0	6.0
Climbing								
40. Up								7.5
41. Down								2.5

i-20lb; ii-22lb; iii-2.5mph; iv-3.5mph; v-50lb; vi-20lb, 2.5mph

Table 10

Average Kcal/Minute and Average WBGT (°C) for Each Season, by Work Area, Plant, and Job

Work Area	Plant No.	Job No.*	Total No. Hours Followed	Average Kcal/Min	Season 1 Average WBGT	Season 2 Average WBGT	Season 3 Average WBGT	All Year Average WBGT
Annealing	7	6015	6.2	2.79	17.24	20.97	26.85	21.51
		6016	.8	2.43	17.24	20.97	26.85	21.51
		7181	14.6	2.73	17.24	20.97	26.85	21.51
		7182	12.1	2.64	17.24	20.97	26.85	21.51
Billet, Bloom, and Slab Mills	1	4036	2.1	2.29	--	18.05	27.04	18.05
	2	4153	3.7	3.05	--	18.64	--	18.64
	5	4153	3.4	2.66	18.77	21.78	23.23	21.39
Blast Furnace	1	3143	9.8	3.51	16.71	23.20	28.14	22.81
		3147	8.1	3.21	16.87	23.38	28.29	22.98
		3199	7.8	2.81	15.75	22.12	27.27	21.81
	2	3143	20.1	3.33	14.14	20.58	28.96	21.06
		3147	14.3	3.72	14.60	21.31	29.34	21.64
		3199	12.7	2.48	12.60	18.14	27.66	19.13
	5	3107	4.1	3.79	11.14	21.37	--	21.37
		3143	4.4	3.11	13.55	22.95	--	22.95
		3147	3.1	3.38	14.73	23.72	--	23.72
		3199	1.3	2.27	11.51	21.61	--	21.61
	6	3107	11.7	3.31	9.75	15.83	25.91	16.83
		3143	16.1	3.08	9.73	15.84	25.93	16.84
		3147	15.7	2.80	9.86	15.70	25.79	16.77
		3199	7.0	2.60	11.53	15.66	25.00	16.96

Table 10 (Continued)

Work Area	Plant No.	Job. No.*	Total No. Hours Followed	Average Kcal/Min	Season 1 Average WBGT	Season 2 Average WBGT	Season 3 Average WBGT	All Year Average WBGT
Coke Plant	2	2140	4.3	3.45	15.70	20.50	27.71	21.10
		2170	5.0	3.65	14.94	22.92	30.24	22.76
		2304	6.2	3.00	15.14	19.42	27.25	20.31
	4	2120	7.4	3.41	15.47	30.42	29.23	26.38
		2140	4.6	3.00	14.47	26.29	26.33	23.34
		2170	14.9	3.57	14.56	27.03	26.86	23.87
		2235	2.1	2.26	15.51	30.58	29.34	26.50
		2304	5.1	3.17	14.84	28.07	27.59	24.64
Electric Furnace	3	3342	12.7	3.68	11.25	18.04	26.33	18.42
		3343	9.6	3.66	10.98	17.92	26.14	18.24
		3348	10.3	3.25	9.93	17.43	25.59	17.60
	5	3342	7.8	3.75	--	25.01	--	25.01
		3343	7.4	3.89	--	25.73	--	25.73
		3348	2.3	2.89	--	26.25	--	26.25
Foundry	6	3403	12.0	4.49	9.71	17.17	23.61	16.91
		3419	3.1	2.37	9.71	17.17	23.61	16.91
		3434	14.0	5.12	9.71	17.17	23.61	16.91
		3992	7.8	4.35	9.71	17.17	23.61	16.91
		3993	5.5	3.59	9.71	17.17	23.61	16.91
		3994	7.2	3.42	9.71	17.17	23.61	16.91

Table 10 (Continued)

Work Area	Plant No.	Job No.*	Total No. Hours Followed	Average Kcal/Min	Season 1 Average WBGT	Season 2 Average WBGT	Season 3 Average WBGT	All Year Average WBGT
Hot Strip Rolling	2	6481	10.3	2.31	--	21.39	26.19	21.39
	7	6423	4.8	3.33	15.51	--	24.10	19.81
Merchant Mill	4	5535	4.1	4.00	--	19.56	25.00	19.56
		5543	3.4	3.12	--	19.77	25.00	19.77
		5551	5.0	2.47	--	19.56	25.00	19.56
		5553	3.6	2.93	--	19.56	25.00	19.56
	5	5551	3.3	2.79	14.83	24.13	26.51	22.40
		5580	3.9	2.58	15.32	24.20	26.67	22.60
		5601	6.3	3.05	18.05	24.63	27.56	23.72
Open Hearth	1	3360	11.7	2.64	13.83	20.05	26.69	20.16
		3361	4.6	3.32	15.06	22.99	30.11	22.78
		3364	6.0	3.77	15.75	25.01	32.58	24.59
		3365	10.3	3.21	14.78	22.50	29.60	22.35
		3502	2.4	2.02	13.58	19.41	25.93	19.58
		3505	2.3	2.55	13.58	19.41	25.93	19.58
		3507	3.1	2.04	13.58	19.41	25.93	19.58
		3559	4.0	2.27	13.58	19.41	25.93	19.58
		3583	16.8	2.97	14.77	22.47	29.56	22.31

Table 10 (Continued)

Work Area	Plant No.	Job No.*	Total No. Hours Followed	Average Kcal/Min	Season 1 Average WBGT	Season 2 Average WBGT	Season 3 Average WBGT	All Year Average WBGT
Open Hearth (Continued)	2	3360	6.6	3.01	13.12	21.95	26.39	20.85
		3361	9.0	2.95	17.31	25.19	29.34	24.25
		3365	16.3	2.87	12.74	21.63	26.09	20.52
		3502	3.9	2.12	11.23	20.34	24.83	19.18
		3505	2.3	2.87	11.23	20.34	24.83	19.18
		3507	1.5	2.14	11.23	20.34	24.83	19.18
		3509	5.6	2.28	11.23	20.34	24.83	19.18
		3519	4.3	2.08	11.23	20.34	24.83	19.18
		3539	10.2	2.59	11.59	20.46	24.83	19.33
		3583	17.9	3.43	14.18	22.86	27.28	21.79
Plate Mill	1	5642	5.0	2.15	--	15.65	26.07	15.65
		5649	5.9	2.52	--	25.04	31.88	25.04
		5656	1.7	2.05	--	15.65	26.07	15.65
		5659	4.9	2.09	--	15.65	26.07	15.65
		5669	7.8	2.65	--	25.06	31.74	25.06
		5673	5.6	2.37	--	16.13	26.36	16.13
		5707	4.3	2.50	--	26.91	34.35	26.91
		5709	3.1	2.45	--	17.96	27.50	17.96
		5719	2.7	2.52	--	15.91	26.23	15.91
Power and Fuel	1	1707	3.1	2.38	18.49	23.64	29.23	23.75
		1747	4.1	4.28	18.49	23.64	29.23	23.75
		1754	10.1	2.61	18.49	23.64	29.23	23.75

Table 10 (Continued)

Work Area	Plant No.	Job No.*	Total No. Hours Followed	Average Kcal/Min	Season 1 Average WBGT	Season 2 Average WBGT	Season 3 Average WBGT	All Year Average WBGT
Power and Fuel (Continued)	4	1750	8.7	2.67	23.94	19.95	24.88	19.95
	5	1702	2.7	4.07	10.72	14.99	24.36	16.27
		1704	5.4	4.52	10.72	14.99	24.36	16.27
		1725	5.7	2.97	10.72	14.99	24.36	16.27
		1754	2.1	2.73	10.72	14.99	24.36	16.27
	6	1707	9.7	2.66	15.39	17.19	26.04	18.95
		1750	14.3	3.13	16.66	18.61	26.40	20.07
		1752	13.5	3.00	16.75	18.73	26.43	20.15
		1754	14.6	2.81	15.97	17.93	26.56	19.60

* See Table 5 for job titles

-- Indicates no measurements taken

Table 11

Causes of Death and ICD Codes According to the Seventh Revision of the International List

Last Digit for Tables 14, 16, 18	Cause of Death	ICD Code
1	All Causes	1-999
2	All Cancers	140-205
3	Buccal and Pharyngeal Cancer	140-148
4	Digestive and Perotoneal Cancer	150-159
5	Respiratory Cancer	160-164
6	Cancer of Lungs, Bronchus, Trachea	162-163
7	Other Respiratory Cancer	160, 161, 164
8	Genito-Urinary Cancer	177-181
9	Cancer of Prostate	177
10	Testis and Other Genital Organs	178-179
11	Cancer of Kidney	180
12	Bladder and Other Urinary Organs	181
13	Lymphatic and Hematopoietic Tissues	200-205
14	Skin Cancer	190-191
15	All Other Cancers	165, 170, 192-199
16	Cardiovascular-Renal Disease	330-334, 400-468 592-594
17	Vascular Lesions of CNS	330-334
18	Arteriosclerotic Heart Disease	420-422
19	Hypertensive Heart Disease	440-447
20	Other Cardiovascular-Renal Disease	400-419, 423-439, 448-468, 592-594
21	Nonmalignant Respiratory Disease	470-527
22	Pneumoconiosis	523-524
23	Other Respiratory Disease	470-522, 525-527
24	Nonmalignant Digestive Disease	530-587
25	Cirrhosis of Liver	581
26	Other Digestive Disease	530-580, 582-587
27	Tuberculosis of Respiratory System	1-8
28	Diabetes Mellitus	260
29	Accidents	800-962
30	Homicides and Suicides	963-964, 970-985
31	Ill-Defined Causes	780-795
32	All Other Causes	Remainder (1-999)

Table 12

Observed and Expected Mortality, 1953-1970, and Relative Risks[1] by Cause of Death, for Men Who Ever Worked Through 1953 in a Job with Presumed Heat Exposure or in a Job Surveyed[+]

CAUSE OF DEATH	Jobs with Presumed Heat Exposure N = 13566			Jobs Surveyed N = 4868		
	Obs.	Exp.	RR	Obs.	Exp.	RR
All Causes	3620	3655.3	0.98	1234	1322.1	0.88**
All Cancers	819	801.0	1.05	297	299.7	0.99
Buccal and Pharyngeal Cancer	28	25.4	1.23	13	10.5	1.43
Digestive and Perotoneal Cancer	264	267.1	0.97	99	101.2	0.97
Respiratory Cancer	277	264.0	1.13	100	97.8	1.04
Cancer of Lungs, Bronchus, Trachea	257	245.3	1.12	94	91.9	1.04
Other Respiratory Cancer	20	18.7	1.19	6	5.9	1.02
Genito-Urinary Cancer	101	93.1	1.23	38	33.8	1.22
Cancer of Prostate	53	51.4	1.08	21	20.3	1.06
Cancer of Kidney	22	16.6	2.22	8	4.9	2.31
Bladder and Other Urinary Organs	25	22.6	1.29	9	7.8	1.25
Lymphatic and Hematopoietic Tissues	67	68.8	0.94	17	24.5	0.57
Skin Cancer	5	5.5	0.83	1	1.9	--
All Other Cancers	77	77.1	1.00	29	30.0	0.95

1. Significance of Relative Risk (RR) based on Summary Chi-Square with one degree of freedom.
* Significant at 5% level; ** Significant at 1% level; -- Less than 5 deaths observed and expected.
\+ For a list of 90 jobs surveyed, see Table 5.

Table 12 (Continued)

Observed and Expected Mortality, 1953-1970, and Relative Risks[1] by Cause of Death, for Men Who Ever Worked Through 1953 in a Job with Presumed Heat Exposure or in a Job Surveyed[+]

CAUSE OF DEATH	Jobs with Presumed Heat Exposure N = 13566			Jobs Surveyed N = 4868		
	Obs.	Exp.	RR	Obs.	Exp.	RR
Cardiovascular-Renal Disease	1971	2027.1	0.94	654	720.3	0.85**
Vascular Lesions of CNS	286	294.3	0.94	106	110.3	0.94
Arteriosclerotic Heart Disease	1383	1428.4	0.93	431	494.2	0.81**
Hypertensive Heart Disease	113	117.4	0.91	45	48.2	0.89
Other Cardiovascular-Renal Disease	189	187.0	1.02	72	67.5	1.10
Nonmalignant Respiratory Disease	157	156.8	1.00	58	59.3	0.97
Pneumoconiosis	7	7.4	0.91	1	2.5	--
Other Respiratory Disease	150	149.4	1.01	57	56.8	1.01
Nonmalignant Digestive Disease	208	195.3	1.15	73	68.3	1.11
Cirrhosis of Liver	98	97.8	1.00	29	33.3	0.82
Other Digestive Disease	110	97.5	1.31	44	35.0	1.48
Tuberculosis of Respiratory System	24	21.7	1.24	5	7.9	0.53
Diabetes Mellitus	54	52.9	1.05	18	17.5	1.05
Accidents	158	156.1	1.03	49	55.1	0.84
Homicides and Suicides	50	58,1	0.73	18	22.3	0.74
Ill-Defined Causes	71	67.6	1.13	23	24.8	0.88
All Other Causes	108	118.7	0.82	39	47.2	0.75

1. Significance of Relative Risk (RR) based on Summary Chi-Sqaure with one degree of freedom.
* Significant at 5% level; ** Significant at 1% level; -- Less than 5 deaths observed and expected.
\+ For a list of 90 jobs surveyed, see Table 5.

Table 13

Listing of Jobs* by 2 Categories Each of Average Kcal/Minute and Average WBGT (°C), for Season 3

I WBGT ≤ 26.33 kcal/minute ≤ 2.90		II WBGT ≤ 26.33 kcal/minute > 2.90	
4-6-3147	4-6-3199	3-4-2140	4-6-3107
5-1-3502	5-1-3505	4-6-3143	7-3-3342
5-1-3507	5-1-3559	7-3-3343	7-3-3348
5-2-3365	5-2-3502	8-6-3403	8-6-3434
5-2-3505	5-2-3507	8-6-3992	8-6-3993
5-2-3509	5-2-3519	8-6-3994	12-4-5535
5-2-3539	8-6-3419	12-4-5543	12-4-5553
10-5-4153	12-4-5551	28-7-6423	54-5-1702
13-1-5642	13-1-5656	54-5-1704	54-5-1725
13-1-5659	13-1-5719		
28-2-6481	54-4-1750		
54-5-1754	54-6-1707		
III WBGT ≥ 26.33 kcal/minute ≤ 2.90		IV WBGT ≥ 26.33 kcal/minute ≤ 2.90	
3-4-2235	4-1-3199	3-2-2140	3-2-2170
4-2-3199	5-1-3360	3-2-2304	3-4-2120
10-1-4036	12-5-5551	3-4-2170	3-4-2304
12-5-5580	13-1-5649	4-1-3143	4-1-3147
13-1-5669	13-1-5673	4-2-3143	4-2-3147
13-1-5707	13-1-5709	5-1-3361	5-1-3364
21-7-6015	21-7-6016	5-1-3365	5-1-3583
21-7-7181	21-7-7182	5-2-3360	5-2-3361
54-1-1707	54-1-1754	12-5-5601	5-2-3583
54-6-1754		54-6-1750	54-1-1747
			54-6-1752

*Listed by Area No., Plant No., and Job No.

Table 14

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: ALL CAUSES

PACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33° C								WBGT > 26.33° C							
	KCAL/MIN ≤ 2.9 (I)				KCAL/MIN > 2.9 (II)				KCAL/MIN ≤ 2.9 (III)				KCAL/MIN > 2.9 (IV)			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1259	324	353.3	0.89	993	230	241.2	0.93	690	193	216.9	0.85	1591	418	458.0	0.86*
< 6 MOS.	168	50	47.7	1.23	164	27	24.2	1.39	49	11	11.3	0.91	129	26	26.8	0.91
6 MOS. - 1 YR.	155	40	42.4	0.76	120	17	17.8	0.89	62	17	16.0	1.34	177	37	38.1	0.85
1 - 4 YRS.	542	114	129.7	0.75*	344	70	74.3	0.87	258	61	68.5	0.79	617	122	135.0	0.79
5 - 9 YRS.	192	58	51.8	1.23	176	47	50.4	0.88	174	41	45.6	0.82	331	95	96.9	0.96
10 - 14 YRS.	90	29	40.4	0.64*	78	31	25.5	1.37	76	25	31.5	0.74	167	54	65.3	0.74
15 + YRS.	103	33	46.1	0.67*	111	38	42.3	0.87	71	38	35.2	1.11	170	84	85.2	0.98

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 15

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: ALL CANCERS

RACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33°C, KCAL/MIN ≤ 2.9 (I)				WBGT ≤ 26.33°C, KCAL/MIN > 2.9 (II)				WBGT > 26.33°C, KCAL/MIN ≤ 2.9 (III)				WBGT > 26.33°C, KCAL/MIN > 2.9 (IV)			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1250	69	73.7	0.92	993	39	45.4	0.83	690	54	49.2	1.12	1591	119	115.4	1.05
< 6 MOS.	168	13	11.6	2.19	164	4	4.5	--	49	3	2.3	--	129	7	7.8	0.55
6 MOS. - 1 YR.	155	8	9.3	0.63	120	2	2.1	--	62	4	5.2	0.36	177	10	11.5	0.47
1 - 4 YRS.	542	24	27.9	0.73	344	13	14.0	0.84	258	18	21.3	0.61	617	37	38.6	0.87
5 - 9 YRS.	192	10	9.3	1.13	176	11	9.2	1.32	174	12	14.0	0.73	331	22	24.4	0.76
10 - 14 YRS.	90	5	6.8	0.70	78	4	3.7	--	76	6	6.1	0.99	167	20	19.7	1.03
15 + YRS.	103	9	9.8	0.91	111	5	8.5	0.57	71	11	7.9	1.44	170	23	19.8	1.23

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 16

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: DIGESTIVE AND PERITONEAL CANCER

RACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33°C								WBGT > 26.33°C							
	KCAL/MIN ≤ 2.9 I				KCAL/MIN > 2.9 II				KCAL/MIN ≤ 2.9 III				KCAL/MIN > 2.9 IV			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1250	20	23.7	0.82	993	11	16.0	0.63	690	28	19.5	1.58*	1591	34	34.2	0.99
< 6 MOS.	108	2	2.1	--	164	0	1.2	--	49	2	1.8	--	129	1	1.5	--
6 MOS. - 1 YR.	155	3	4.3	--	120	0	1.1	--	62	1	1.8	--	177	3	4.3	--
1 - 4 YRS.	542	6	6.9	0.80	344	6	7.4	0.55	258	8	9.6	0.59	617	13	10.9	1.54
5 - 9 YRS.	192	4	3.6	--	176	2	2.9	--	174	4	6.4	0.36	331	10	10.3	0.93
10 - 14 YRS.	90	3	2.7	--	78	2	1.7	--	76	4	2.1	--	167	2	4.2	--
15 + YRS.	103	2	3.0	--	111	1	2.3	--	71	9	3.2	3.16**	170	5	7.1	0.66

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 17

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: LYMPHATIC & HEMATOPOIETIC TISSUES

RACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33°C, KCAL/MIN ≤ 2.9 (I)				WBGT ≤ 26.33°C, KCAL/MIN > 2.9 (II)				WBGT > 26.33°C, KCAL/MIN ≤ 2.9 (III)				WBGT > 26.33°C, KCAL/MIN > 2.9 (IV)			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1250	1	6.5	0.14*	993	6	3.9	1.77	690	1	4.3	--	1591	6	9.6	0.48
< 6 MOS.	168	1	1.0	--	164	1	0.7	--	49	0	0.0	--	129	1	0.6	--
6 MOS. - 1 YR.	155	0	0.9	--	120	0	0.0	--	62	0	0.8	--	177	0	0.8	--
1 - 4 YRS.	542	0	1.5	--	344	2	1.2	--	258	0	0.8	--	617	2	2.8	--
5 - 9 YRS.	192	0	0.4	--	176	3	1.8	--	174	1	1.6	--	331	0	1.3	--
10 - 14 YRS.	90	0	0.7	--	78	0	0.5	--	76	0	0.8	--	167	2	1.9	--
15 + YRS.	103	0	0.7	--	111	0	0.4	--	71	0	0.5	--	170	1	1.2	--

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 18

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: CARDIOVASCULAR-RENAL DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33°C, KCAL/MIN ≤ 2.9 (I)				WBGT ≤ 26.33°C, KCAL/MIN > 2.9 (II)				WBGT > 26.33°C, KCAL/MIN ≤ 2.9 (III)				WBGT > 26.33°C, KCAL/MIN > 2.9 (IV)			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1250	168	203.5	0.90	993	144	135.7	1.09	690	100	124.6	0.76*	1591	186	234.3	0.72**
< 6 MOS.	168	30	25.2	2.16	164	19	14.2	2.96*	49	6	5.4	1.55	129	13	10.4	2.10
6 MOS. - 1 YR.	155	22	21.4	1.19	120	11	9.7	1.86	62	10	7.9	5.49	177	15	13.8	1.81
1 - 4 YRS.	542	65	70.1	0.84	344	40	42.8	0.87	258	33	33.7	0.96	617	48	57.5	0.70
5 - 9 YRS.	192	37	29.6	1.51	176	26	27.9	0.87	174	22	22.7	0.94	331	46	47.0	0.96
10 - 14 YRS.	90	19	24.4	0.74	78	23	16.5	1.76	76	13	18.4	0.65	167	24	32.0	0.68
15 + YRS.	103	15	27.8	0.50*	111	25	23.6	1.07	71	16	21.7	0.68	170	40	51.9	0.72

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 19

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: ARTERIOSCLEROTIC HEART DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33°C								WBGT > 26.33°C							
	KCAL/MIN ≤ 2.9 I				KCAL/MIN > 2.9 II				KCAL/MIN ≤ 2.9 III				KCAL/MIN > 2.9 IV			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1250	137	148.5	0.90	993	93	94.3	0.98	690	67	88.7	0.71*	1591	119	154.2	0.71**
< 6 MOS.	168	24	20.9	2.17	164	12	8.4	3.73	49	2	2.0	--	129	8	7.4	1.32
6 MOS. - 1 YR.	155	16	16.9	1.55	120	6	6.7	0.26	62	6	4.9	3.76	177	5	5.3	0.72
1 - 4 YRS.	542	43	50.1	0.71	344	21	25.5	0.70	258	22	23.5	0.90	617	31	37.6	0.72
5 - 9 YRS.	192	29	21.1	1.74*	176	19	19.6	0.95	174	15	16.6	0.83	331	35	35.0	1.11
10 - 14 YRS.	90	13	17.9	0.68	78	18	11.8	1.90*	76	8	13.7	0.53	167	15	22.0	0.61
15 + YRS.	103	10	19.7	0.48*	111	17	16.4	1.05	71	14	15.1	0.91	170	25	32.9	0.72

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 20

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: NONMALIGNANT DIGESTIVE DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33°C, KCAL/MIN ≤ 2.9 (I)				WBGT ≤ 26.33°C, KCAL/MIN > 2.9 (II)				WBGT > 26.33°C, KCAL/MIN ≤ 2.9 (III)				WBGT > 26.33°C, KCAL/MIN > 2.9 (IV)			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1250	23	19.3	1.24	993	9	11.1	0.76	690	11	10.3	1.08	1591	25	21.9	1.19
< 6 MOS.	168	3	3.7	--	164	0	1.1	--	49	1	1.5	--	129	1	1.7	--
6 MOS. - 1 YR.	155	5	5.9	0.66	120	2	2.0	--	62	0	0.5	--	177	3	3.9	--
1 - 4 YRS.	542	8	6.8	1.27	344	2	2.4	--	258	2	2.4	--	617	8	7.2	1.22
5 - 9 YRS.	192	3	4.1	--	176	0	2.0	--	174	1	1.9	--	331	2	4.6	--
10 - 14 YRS.	90	1	1.9	--	78	2	1.3	--	76	2	1.4	--	167	3	3.3	--
15 + YRS.	103	3	2.0	--	111	3	2.0	--	71	5	1.7	3.48*	170	8	3.5	2.75*

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 21

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1] BY LENGTH OF EXPOSURE, AVERAGE WBGT, AND AVERAGE KCAL/MINUTE FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: OTHER DIGESTIVE DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	WBGT ≤ 26.33°C, KCAL/MIN ≤ 2.9 (I)				WBGT ≤ 26.33°C, KCAL/MIN > 2.9 (II)				WBGT > 26.33°C, KCAL/MIN ≤ 2.9 (III)				WBGT > 26.33°C, KCAL/MIN > 2.9 (IV)			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	1250	6	7.1	1.16	993	6	6.2	0.96	690	8	5.2	1.75	1591	20	12.2	2.04*
< 6 MOS.	168	0	1.3	--	164	0	0.3	--	49	1	1.5	--	129	1	1.7	--
6 MOS. - 1 YR.	155	3	3.1	--	120	1	0.8	--	62	0	0.1	--	177	3	2.1	--
1 - 4 YRS.	542	1	0.2	--	344	0	0.4	--	258	1	0.5	--	617	5	2.3	--
5 - 9 YRS.	192	1	1.5	--	176	0	1.7	--	174	1	0.5	--	331	2	2.8	--
10 - 14 YRS.	90	1	0.6	--	78	2	1.0	--	76	2	0.8	--	167	3	2.3	--
15 + YRS.	103	2	1.0	--	111	3	1.5	--	71	3	1.0	--	170	6	2.3	3.35*

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 22

Listing of Jobs* by 4 Categories of Average WBGT (°C), for Season 3

I		II	
WBGT ≤ 24.88		24.88 < WBGT ≤ 26.33	
5-2-3502	5-2-3505	3-4-2140	4-6-3107
5-2-3507	5-2-3509	4-6-3143	4-6-3147
5-2-3519	5-2-3539	4-6-3199	5-1-3502
8-6-3403	8-6-3419	5-1-3505	5-1-3507
8-6-3434	8-6-3992	5-1-3559	5-2-3365
8-6-3993	8-6-3994	7-3-3342	7-3-3343
10-5-4153	28-7-6423	7-3-3348	12-4-5535
54-4-1750	54-5-1702	12-4-5543	12-4-5551
54-5-1704	54-5-1725	12-4-5553	13-1-5642
54-5-1754		13-1-5656	13-1-5659
		13-1-5719	28-2-6481
		54-6-1707	
III		IV	
26.33 < WBGT ≤ 27.59		WBGT > 27.59	
3-2-2304	3-4-2170	3-2-2140	3-2-2170
3-4-2304	4-1-3199	3-4-2120	3-4-2235
5-1-3360	5-2-3360	4-1-3143	4-1-3147
10-1-4036	5-2-3583	4-2-3143	4-2-3147
12-5-5580	12-5-5551	4-2-3199	5-1-3361
13-1-5673	12-5-5601	5-1-3364	5-1-3365
21-7-6015	13-1-5709	5-1-3583	5-2-3361
21-7-7181	21-7-6016	13-1-5649	13-1-5669
54-6-1750	21-7-7182	13-1-5707	54-1-1707
54-6-1754	54-6-1752	54-1-1747	54-1-1754

*Listed by Area No., Plant No., and Job No.

Table 23

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND AVERAGE WBGT FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: ALL CAUSES

RACE: TOTAL

LENGTH OF EXPOSURE	I WBGT ≤ 24.88°C				II 24.88°C < WBGT ≤ 26.33°C				III 26.33°C < WBGT ≤ 27.59°C				IV WBGT > 27.59°C			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	817	172	192.4	0.86	1426	382	404.4	0.92	951	254	292.8	0.83**	1330	357	380.6	0.90
< 6 MOS.	116	12	12.7	0.86	213	63	58.2	1.39	63	14	13.8	1.04	110	24	25.0	0.85
6 MOS. - 1 YR.	92	10	13.1	0.62	174	45	44.5	1.07	79	18	.9	1.36	159	37	36.3	1.13
1 - 4 YRS.	305	58	62.8	0.86	568	118	135.5	0.73*	361	72	84.9	0.74	519	112	121.0	0.82
5 - 9 YRS.	147	34	34.3	0.99	210	62	59.2	1.09	197	55	55.4	0.99	311	84	87.4	0.91
10 - 14 YRS.	83	28	28.3	0.99	89	32	35.4	0.87	111	29	43.8	0.56*	131	47	51.4	0.88
15 + YRS.	74	30	35.1	0.81	172	62	73.3	0.81	140	60	68.1	0.96	100	53	52.0	1.03

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 24

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]
BY LENGTH OF EXPOSURE AND AVERAGE WBGT FOR SEASON 3
WORK AREA: ALL WORK AREAS
CAUSE OF DEATH: ALL CANCERS
RACE: TOTAL

LENGTH OF EXPOSURE	I WBGT ≤ 24.88 °C				II 24.88 °C < WBGT ≤ 26.33 °C				III 26.33 °C < WBGT ≤ 27.59 °C				IV WBGT > 27.59 °C			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	817	38	38.3	0.99	1426	70	80.8	0.84	951	72	66.6	1.10	1330	101	94.0	1.12
< 6 MOS.	116	1	1.5	--	213	16	14.7	1.50	63	4	3.2	--	110	7	7.2	0.80
6 MOS. - 1 YR.	92	3	2.0	--	174	7	9.1	0.42	79	6	7.1	0.40	159	8	9.5	0.46
1 - 4 YRS.	305	13	13.3	0.96	568	23	27.0	0.70	361	19	22.4	0.70	519	37	36.8	1.02
5 - 9 YRS.	147	8	6.5	1.31	210	11	10.6	1.08	197	15	16.5	0.82	311	20	21.3	0.85
10 - 14 YRS.	83	7	5.5	1.32	89	3	5.2	0.55	111	8	10.8	0.68	131	18	13.7	1.52
15 + YRS.	74	6	7.0	0.84	172	10	15.7	0.61	140	20	15.5	1.33	100	11	11.0	1.00

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 25

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND AVERAGE WBGT FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: GENITO-URINARY CANCER

RACE: TOTAL

LENGTH OF EXPOSURE	I WBGT ≤ 24.88 °C				II 24.88 °C < WBGT ≤ 26.33 °C				III 26.33 °C < WBGT ≤ 27.59 °C				IV WBGT > 27.59 °C			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	817	4	3.8	--	1426	6	9.3	0.60	951	7	7.3	0.96	1330	19	12.3	2.07*
< 6 MOS.	116	0	0.0	--	213	2	1.7	--	63	0	0.0	--	110	0	0.1	--
6 MOS. - 1 YR.	92	0	0.0	--	174	0	0.0	--	79	1	1.0	--	159	1	1.0	--
1 - 4 YRS.	305	1	0.7	--	568	2	2.5	--	361	4	3.2	--	519	10	8.2	2.72
5 - 9 YRS.	147	1	0.5	--	210	1	0.7	--	197	2	1.3	--	311	3	1.4	--
10 - 14 YRS.	83	1	0.7	--	89	0	0.5	--	111	0	1.2	--	131	3	1.5	--
15 + YRS.	74	1	1.5	--	172	1	2.4	--	140	0	1.7	--	100	2	2.1	--

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 26

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND AVERAGE WBGT FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: CARDIOVASCULAR-RENAL DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	I WBGT ≤ 24.88°C				II 24.88°C < WBGT ≤ 26.33°C				III 26.33°C < WBGT ≤ 27.59°C				IV WBGT > 27.59°C			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	817	96	105.4	0.89	1426	236	233.9	1.01	951	127	164.2	0.73**	1330	159	197.1	0.74**
< 6 MOS.	116	8	6.5	1.78	213	39	31.9	2.66*	63	8	6.8	1.88	110	11	9.1	1.99
6 MOS. - 1 YR.	92	5	5.9	0.69	174	27	24.5	3.08	79	7	6.2	2.89	159	19	16.2	3.27
1 - 4 YRS.	305	30	33.8	0.82	568	70	77.9	0.78	361	36	41.6	0.78	519	45	52.3	0.73
5 - 9 YRS.	147	18	17.7	1.03	210	39	32.8	1.37	197	31	27.6	1.20	311	40	43.4	0.84
10 - 14 YRS.	83	17	16.2	1.06	89	24	22.2	1.11	111	15	23.2	0.58	131	19	26.6	0.64
15 + YRS.	74	18	20.0	0.88	172	37	43.0	0.84	140	30	42.1	0.66*	100	25	32.2	0.72

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 27

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]
BY LENGTH OF EXPOSURE AND AVERAGE WBGT FOR SEASON 3
WORK AREA: ALL WORK AREAS
CAUSE OF DEATH: ARTERIOSCLEROTIC HEART DISEASE
RACE: TOTAL

LENGTH OF EXPOSURE	I WBGT ≤ 24.88°C				II 24.88°C < WBGT ≤ 26.33°C				III 26.33°C < WBGT ≤ 27.59°C				IV WBGT > 27.59°C			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	817	65	73.0	0.87	1426	165	169.2	0.97	951	81	113.8	0.67**	1330	105	131.0	0.74**
< 6 MOS.	116	5	3.2	2.42	213	30	25.8	2.55	63	4	4.4	--	110	6	4.9	1.78
6 MOS. - 1 YR.	92	3	4.1	--	174	21	19.4	2.39	79	3	3.2	--	159	9	8.1	1.83
1 - 4 YRS.	305	18	22.6	0.70	568	44	52.5	0.67	361	23	28.6	0.72	519	29	34.4	0.73
5 - 9 YRS.	147	13	11.9	1.14	210	30	24.0	1.47	197	20	18.4	1.13	311	33	32.8	1.01
10 - 14 YRS.	83	14	12.2	1.19	89	16	16.3	0.98	111	10	15.9	0.58	131	12	19.3	0.54
15 + YRS.	74	12	13.1	0.90	172	24	30.4	0.77	140	21	29.2	0.68	100	16	19.5	0.79

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 28

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]
BY LENGTH OF EXPOSURE AND AVERAGE WBGT FOR SEASON 3
WORK AREA: ALL WORK AREAS
CAUSE OF DEATH: NONMALIGNANT DIGESTIVE DISEASE
RACE: TOTAL

LENGTH OF EXPOSURE	I WBGT ≤ 24.88°C				II 24.88°C < WBGT ≤ 26.33°C				III 26.33°C < WBGT ≤ 27.59°C				IV WBGT > 27.59°C			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	817	6	9.5	0.57	1426	26	20.6	1.34	951	14	14.2	0.98	1330	22	18.3	1.29
< 6 MOS.	116	0	0.8	--	213	3	4.2	--	63	0	0.8	--	110	2	2.5	--
6 MOS. - 1 YR.	92	1	2.7	--	174	6	4.5	2.18	79	1	0.7	--	159	2	2.9	--
1 - 4 YRS.	305	2	2.3	--	568	8	6.4	1.38	361	2	3.4	--	519	8	6.4	1.53
5 - 9 YRS.	147	0	1.5	--	210	3	4.4	--	197	0	2.7	--	311	3	4.7	--
10 - 14 YRS.	83	1	1.5	--	89	2	1.6	--	111	4	2.5	--	131	1	2.0	--
15 + YRS.	74	2	1.4	--	172	4	3.4	--	140	7	3.0	2.55*	100	6	2.2	3.85*

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 29

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND AVERAGE WBGT FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: OTHER DIGESTIVE DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	I WBGT ≤ 24.88 °C				II 24.88°C < WBGT ≤ 26.33°C				III 26.33°C < WBGT ≤ 27.59°C				IV WBGT > 27.59°C			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	817	3	4.5	--	1426	11	8.8	1.33	951	11	7.6	1.55	1330	17	10.1	2.22*
< 6 MOS.	116	0	0.3	--	213	0	1.5	--	63	0	0.8	--	110	2	2.5	--
6 MOS. - 1 YR.	92	1	1.0	--	174	3	2.9	--	79	1	0.2	--	159	2	2.0	--
1 - 4 YRS.	305	0	0.4	--	568	1	0.2	--	361	2	0.6	--	519	4	2.2	--
5 - 9 YRS.	147	0	1.0	--	210	1	2.1	--	197	0	1.6	--	311	3	2.8	--
10 - 14 YRS.	83	1	1.0	--	89	2	0.4	--	111	4	1.9	--	131	1	0.9	--
15 + YRS.	74	1	0.8	--	172	4	2.4	--	140	4	1.8	--	100	5	1.6	5.37*

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 30

Listing of Jobs* Classified by

ACGIH TLV, for Season 3

Above TLV

3-2-2170	4-2-3147	5-1-3361	5-1-3364
13-1-5649	13-1-5669	13-1-5707	

Below TLV

3-2-2140	3-2-2304	3-4-2120	3-4-2140
3-4-2170	3-4-2235	3-4-2304	4-1-3143
4-1-3147	4-1-3199	4-2-3143	4-2-3199
4-6-3107	4-6-3143	4-6-3147	4-6-3199
5-1-3360	5-1-3365	5-1-3502	5-1-3505
5-1-3507	5-1-3559	5-1-3583	5-2-3360
5-2-3361	5-2-3507	5-2-3365	5-2-3502
5-2-3505	5-2-3583	5-2-3509	5-2-3519
5-2-3539	8-6-3403	7-3-3342	7-3-3343
7-3-3348	8-6-3993	8-6-3419	8-6-3434
8-6-3992	12-4-5535	8-6-3994	10-1-4036
10-5-4153	12-5-5551	12-4-5543	12-4-5551
12-4-5553	13-1-5656	12-5-5580	12-5-5601
13-1-5642	13-1-5719	13-1-5659	13-1-5673
13-1-5709	21-7-7182	21-7-6015	21-7-6016
21-7-7181	54-1-1747	28-2-6481	28-7-6423
54-1-1707	54-5-1704	54-1-1754	54-4-1750
54-5-1702	54-6-1750	54-5-1725	54-5-1754
54-6-1707		54-6-1752	54-6-1754

*Listed by Area No., Plant No., and Job No.

Table 31

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND ACGIH TLV FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: ALL CAUSES

RACE: TOTAL

LENGTH OF EXPOSURE	I BELOW TLV				II ABOVE TLV			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	4254	1086	1162.9	0.89**	270	79	90.1	0.84
< 6 MOS.	452	101	97.1	1.19	19	5	5.3	0.76
6 MOS. - 1 YR.	446	100	101.4	0.92	36	6	7.5	0.29
1 - 4 YRS.	1568	320	341.9	0.82*	116	30	34.3	0.76
5 - 9 YRS.	838	220	221.8	0.98	55	15	14.8	1.02
10 - 14 YRS.	424	129	150.3	0.79*	19	9	8.5	1.07
15 + YRS.	526	216	238.6	0.87	25	14	12.1	1.22

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 32

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND ACGIH TLV FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: LYMPHATIC & HEMATOPOIETIC TISSUES

RACE: TOTAL

LENGTH OF EXPOSURE	I BELOW TLV				II ABOVE TLV			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	4254	12	20.4	0.48*	270	2	2.1	--
< 6 MOS.	452	3	2.3	--	19	0	0.0	--
6 MOS. - 1 YR.	446	0	0.9	--	36	0	0.8	--
1 - 4 YRS.	1568	3	4.6	--	116	0	0.4	--
5 - 9 YRS.	838	3	3.9	--	55	2	1.0	--
10 - 14 YRS.	424	1	3.4	--	19	0	0.2	--
15 + YRS.	526	2	3.2	--	25	0	0.2	--

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 33

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND ACGIH TLV FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: CARDIOVASCULAR-RENAL DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	I BELOW TLV				II ABOVE TLV			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	4254	582	638.3	0.87**	270	36	49.2	0.68*
< 6 MOS.	452	60	50.6	2.41**	19	2	1.8	--
6 MOS. - 1 YR.	446	54	50.9	1.66	36	3	2.7	--
1 - 4 YRS.	1568	165	174.8	0.85	116	13	15.4	0.74
5 - 9 YRS.	838	117	114.6	1.05	55	8	7.2	1.18
10 - 14 YRS.	424	75	84.8	0.84	19	4	4.8	--
15 + YRS.	526	111	142.0	0.72**	25	6	7.7	0.73

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 34

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]
BY LENGTH OF EXPOSURE AND ACGIH TLV FOR SEASE 3
WORK AREA: ALL WORK AREAS
CAUSE OF DEATH: ARTERIOSCLEROTIC HEART DISEASE
RACE: TOTAL

LENGTH OF EXPOSURE	I BELOW TLV				II ABOVE TLV			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	4254	393	442.7	0.84**	270	23	32.9	0.66
< 6 MOS.	452	43	37.0	2.39*	19	1	1.1	--
6 MOS. - 1 YR.	446	31	30.8	1.07	36	2	1.9	--
1 - 4 YRS.	1568	103	114.8	0.76	116	10	12.0	0.72
5 - 9 YRS.	838	86	80.8	1.15	55	5	5.9	0.76
10 - 14 YRS.	424	52	59.9	0.82	19	3	3.2	--
15 + YRS.	526	78	98.6	0.74*	25	2	4.3	--

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

Table 35

OBSERVED AND EXPECTED MORTALITY, 1953-1970, AND RELATIVE RISKS[1]

BY LENGTH OF EXPOSURE AND ACGIH TLV FOR SEASON 3

WORK AREA: ALL WORK AREAS

CAUSE OF DEATH: OTHER DIGESTIVE DISEASE

RACE: TOTAL

LENGTH OF EXPOSURE	I BELOW TLV				II ABOVE TLV			
	N	OBS.	EXP.	RR	N	OBS.	EXP.	RR
EVER WORKED THROUGH 1953	4254	36	30.1	1.34	270	6	1.8	4.23**
< 6 MOS.	452	1	2.8	--	19	1	1.3	--
6 MOS. - 1 YR.	446	5	4.3	1.79	36	1	0.8	--
1 - 4 YRS.	1568	6	4.0	3.26	116	1	0.3	--
5 - 9 YRS.	838	4	6.4	0.28	55	1	0.6	--
10 - 14 YRS.	424	6	4.3	1.94	19	1	0.3	--
15 + YRS.	526	14	7.5	2.38*	25	1	0.2	--

1. SIGNIFICANCE OF RELATIVE RISK (RR) BASED ON SUMMARY CHI-SQUARE WITH ONE DEGREE OF FREEDOM.

* SIGNIFICANT AT 5% LEVEL; ** SIGNIFICANT AT 1% LEVEL; -- LESS THAN 5 DEATHS.

APPENDIX A

Description and Maps of Work Areas, Including Changes Over Time and Location Groups

Included in this section are brief, general descriptions of processes occurring in each work area of interest, and information for each plant concerning heat stress variability or changes over time, including a table of these changes (26).

Two factors regarding heat stress appear to be common to almost every job surveyed. First, probably every job is now under a type of incentive plan. Dates of introduction and details of the plans can vary from area-to-area or job-to-job. However, it is possible that for some jobs energy expenditure and/or heat exposure changed following the introduction of these plans. Details are noted for some jobs in the text to follow.

The second common factor is that almost all workers in jobs of interest now work or have usually worked under a schedule of rotating shifts. Usually, each area operates on a schedule of three shifts or turns per day:

Shift 1: Midnight - 8:00 A.M.
Shift 2: 8:00 A.M. - 4:00 P.M.
Shift 3: 4:00 P.M. - Midnight

In general, each worker maintains a schedule of working one shift for a week, then working under the next shift for a week, etc. The week after shift 3 is completed, the cycle begins again with shift 1. Systems of scheduling days off vary. Exceptions to this schedule occur during periods of plant cutbacks, usually due to lack of orders.

Annealing

Plant No. 7

The term annealing refers to the process of heat-treating steel to obtain desired properties. The process consists of heating and cooling the steel in furnaces at controlled rates.

At this plant, the annealing building contains 53 furnaces for heating of coiled steel. Coils are placed onto a base, then covered, and a furnace is placed on top of the covers by an overhead crane. After the coils are heated and cooled, the coils are removed. The process of lifting the furnace can result in intense, temporary heat exposure for surrounding workers. However, the general level of heat in the annealing building depends on the number of furnaces operating and the number of times it is necessary to lift the furnace.

The building is divided into 2 areas, for tin annealing and sheet annealing. The tin annealing side contains 10 furnaces, while the sheet area houses 43 furnaces. Remodeling (after 1970) has resulted in an increase in general heat levels in part of the sheet side, but a decrease in heat in the rest of the building.

There are 2 cranes in the tin side and 6 cranes in the sheet side. An annealer and assistant annealer work in each area, while hookers spend most of their time at the sheet side. Collection and analysis of the data were performed with adjustment for these factors.

Billet, Bloom, and Slab Mills

In billet, bloom and slab mills, a series of operations is performed whereby steel ingots are reduced to square, oblong, round, or other shapes. The names billet, bloom and slab refer to three general shapes and sizes which may be formed from the ingots. Billets are usually square, and blooms are square or slightly oblong, larger than billets. Slabs are oblong, with a greater length and smaller width than billets or blooms.

Before changes in size and shape of the ingot occurs, the steel is reheated at furnaces in the billet, bloom and slab mill, or in soaking pits, which are adjacent to the mill. Thus, heat exposure can be intense for workers in close proximity to the steel during rolling. Heat exposure for a worker can vary depending on the size or shape of the passing steel.

Plant No. 1

The job of interest, craneman, requires work in a cab which reportedly has changed little over time.

Plant No. 2

Although changes in the blooming mill have occurred over time, the job of interest (stamper) apparently has changed very little, with respect to

activity or heat exposure.

Blooms formed in this mill may be 20" square or smaller. Slabs are 17" to 62" in cross-sectional width.

Some change may have occurred in heat exposure for the stamper, since until about 10 years ago water used to run through the shield surrounding his work area. Also, there is glass in the shield of today, which is a fairly recent innovation.

The stamper's normal time on the job per shift is 6½ hours. A portable heater is used in colder months.

Plant No. 5

Measurements were taken at a mill which is part of a primary mill. Before 1959, this mill and a conditioning mill were combined, which caused us to reject some jobs originally of interest.

However, for the job of interest, stamper, duties and heat exposure have not changed for many years, according to safety personnel and the superintendent. The worker is exposed to intervals of intense heat due to passing steel. Maximum size of passing steel is approximately 12" by 12". A worksite fan operating at times in summer is a relatively recent innovation.

Blast Furnace

The purpose of the blast furnace plant is to manufacture iron for use in the open hearth steelmaking process or in the foundry. Basically, the iron is formed by loading iron ore, coke, limestone, and dolomite into the top of the furnace and blowing hot air (blast) into the bottom. The elements are heated for varying lengths of time, depending on the type of furnace. The process of removing the molten iron and slag from the furnace (referred to as casting) is accomplished by allowing these liquids to flow from the furnace along gutter-shaped paths in the ground, called runners. The runners lead to ladles or submarine-shaped cars, which are transported to various areas.

Heat exposure can be intense during the cast for those workers who must work near the runners. Exposure may also be greater than usual for these workers after a cast has been completed, due to the heat of the runners. The introduction of reflective aluminized clothing for wear during the cast (introduced approximately 1950) has decreased heat exposure for some workers.

The physical exertion required for some jobs in a blast furnace area can be great at times. However, it is generally accepted that most jobs in this area are less demanding today, due to:

1) Better lining material for the runners, resulting in less damage to the runners from each cast. This better material was introduced about fifteen years ago.

2) The introduction of large-capacity overhead cranes. These cranes apparently were not common in this area in some plants before 1940. The absence of a large crane meant that workers were required to perform more manual labor, such as clean-up duties.

3) Automatic electric drills to open the tap hole. These were not in general use until approximately fifteen years ago. The workers, in the past, opened the holes manually, using a pneumatic drill. The date of introduction of the automatic drills can vary from plant-to-plant.

Many of the plants have decreased cast-to-cast times today, which may weigh in favor of increased work requirements. Considering all factors, however, most jobs probably are less strenuous today.

Plant No. 1

Four blast furnaces exist at present at the plant. Since the furnaces are similar, data were collected at one of the furnaces. Originally, there were seven blast furnaces at this plant. Three of these were torn down, and the remaining ones have been rebuilt.

For the older furnaces, cycle time (time from cast-to-cast) was approximately 8 hours. Now, cycle time can be as short as 2½ hours. Casting time at present can vary from 15-30 minutes.

Plant No. 2

Early data were collected at Furnace No. 1, which was shut down in June of 1975. Cycle time approximated 3 hours. Cast time averaged 30-35 minutes.

Furnace No. 2 was rebuilt in 1976. All data collected in 1976 were from this furnace. Compared to No. 1, No. 2 has a larger diameter, larger runners, and possibly a slightly longer average cast time. Also, No. 2 requires a 6-man crew as compared to the 4 men required for No. 1.

Plant No. 5

As far in the past as can be determined, there were 6 furnaces at this plant. Three of these furnaces were torn down. However, in place of two of these older furnaces a larger furnace was built, at which contract data were collected.

Cycle time for the older furnaces is approximately 3 hours, while for the newer furnace cycle time is approximately 2 hours and 20 minutes. Casting time for the newer furnace averages 30 minutes.

Plant No. 6

Today there are five similar blast furnaces at this plant; data were collected at one of these furnaces. Cycle time appears to average about 2½ hours. Cast time can vary from 20 minutes to over 1 hour, with an average time of 40-45 minutes.

In the 1930's, there were 11 furnaces, which were smaller than the furnaces of today. These older furnaces had cast-to-cast times of 5-6 hours. Gradually, the newer furnaces of today were built in place of these older furnaces.

Coke Plant

The main purpose of a coke oven is to form the residue coke from the heating of bituminous coal. Although many by-products may be formed and captured in this process and processed in a separate area of the coke plant, the jobs of interest in this study were ones at the coke ovens.

Coke ovens are arranged in units called batteries. The number of ovens per battery and the number of batteries per plant is variable. The basic coking process begins when bituminous coal is loaded into the top of each oven by a larry car. The coal then normally is heated 17-18 hours in each oven. At the end of that time, the coke is "pushed" out of the oven by a machine on the pushing side of the ovens. On the other side, the coking side, the oven door is removed by a door machine and the coke is guided out of the oven through a part of this machine. The coke then falls into a railroad car, called a quenching car, and is taken to a quenching station, where it is sprayed with water for cooling. The coke is then dumped onto a coke wharf, where it is further cooled and remains until further processing.

Batteries are of two types: "gun-type" or "underjet". The difference between the types is reflected in the internal heating systems of the battery. One difference which is important for study purposes is that gun-type batteries have alleys at their base while underjet batteries have basements.

Extensive changes in working conditions have occurred over time, in part due to technological changes often resulting from pollution requirements. In general, many more by-products of the coking process are captured today. Also, coal is now loaded into the oven tops by a "smokeless-charging" procedure, which results in less smoke and heat being emitted. Oven doors, on the sides of the batteries, are now self-sealing; in the past, workers sealed the doors manually, to prevent emission escape.

Labor-management agreements also have changed job conditions. Lidmen, who work on top of the battery, are now away from the job much more than previously, due to contract agreements.

Plant No. 2

There are five batteries of ovens at Plant 2. Data were collected at 2 of these batteries. Although it is believed that heat stress for jobs of interest are similar from battery-to-battery, systems of work relief and the amount of emissions can vary from one unit to another.

Plant No. 4

These coke ovens are comprised of 20 batteries, or 1375 ovens. The number of ovens in each battery varies from 64 to 87. Cycle time per oven can

increase to 20 hours or more under pollution alerts. At this plant today, 16 batteries are gun-type while 4 are underjet fired, although many of these batteries have been rebuilt or have been altered extensively over time. Study data were collected at one gun-type and one underjet-fired battery.

For three batteries (1 unit), the crew size is 21 operating personnel. This includes 3 lidmen, 1 quencher car operator, 1½ heaters, and others. Assistant heaters of gun-type batteries presently work during the day shift only.

Electric Furnace

The electric furnace is a type of steel-making facility in use at two of our plants of interest. The physical layout of the work area is similar to the open hearth area, although electric furnaces are smaller than open hearth furnaces.

One difference between the electric furnace process and the open hearth process is that tapping time for the former is usually less than 10 minutes. This is accomplished by tilting the furnace so that the steel flows into a ladle. Also, no hot iron is poured into the electric furnaces of interest in this study; "cold" metal is used.

Plant No. 3

The present building dates from 1949; before then, similar work areas in other locations were operating. Study data were collected at one of the four furnaces in this area.

Automation has resulted in a decrease in physical exertion requirements for some jobs in this area. For jobs of interest, this has most affected the second and third helper.

Cycle time (time from tap-to-tap) can range from 4 to 5 hours, although average time appears to be 5 hours. Tap time for each furnace is 8-12 minutes.

Plant No. 5

The building which houses the electric furnaces dates from approximately 1942, although company ownership dates from 1949. Presently, there are five electric furnaces at this plant. Three of these furnaces date from the opening of the building; the other two furnaces were added to a new section of the building, after 1958. Study measurements were taken at one of the newer furnaces.

Cycle time is 6-8 hours, although it can be as low as 4½ hours. Tapping time can be as high as 7 minutes, although the average appears to be less than 5 minutes.

Several workers, as at Plant 3, stated that much of the work is easier now, due to automation. Also, it was stated that recent pollution controls have

made the workplace cooler and less smoky.

It has also been stated that incentives (probably introduced in the last 20 years) have resulted in first helpers desiring shorter tap-to-tap times. Whether any workloads have been increased because of this factor remains questionable, however.

Foundry

Plant No. 6

The purpose of a foundry is to make castings, which can be used in other work areas or by other companies in forming molten metal into solid ingots. The castings are formed by the pouring of molten iron or steel into a mold of the desired shape.

At this plant, there are three buildings in the foundry work area. In Building No. 1, referred to as a stool foundry, stool castings are prepared, including pouring and cleaning (chipping). Also, ladles are relined.

In Building No. 2, known as a mold foundry, several different operations occur, before and after the pouring of iron into molds to form castings. In particular, ladles, molds, and patterns, which are placed into the molds prior to pouring, are prepared, pouring occurs, and separation of the casting from the other elements takes place after cooling.

In Building No. 3, chippers clean new castings. The cleaning is usually accomplished, as in Building 1, by a hand-held pneumatic tool.

In general, heat exposure can be great for workers on the pouring platform during pouring, and may also be high at times for other jobs.

Building No. 3 dates from 1954. The other two buildings date from an undetermined year before 1954.

In the pouring process, in Building 2 these changes have occurred over time:

1) Molds used in the pouring process are larger now.

2) Stoppers on the ladles used in pouring also are said to be larger now, which may result in shorter pouring time.

3) Troughs were utilized in the past instead of ladles to pour iron into the molds, according to one employee.

These changes, plus the introduction of aluminized reflective clothing about 1950, may indicate that workers involved in pouring are exposed to less heat today than in the past.

Chippers started on an incentive plan less than two years ago that is based on the number of castings which are cleaned. This may have resulted in increased output for some of these workers.

Hot Strip Rolling and Plate Mills

In these mills, flat-rolled steel products are produced. Heat exposure occurs when the hot steel is passing on the rolling stands. As in the billet, bloom, and slab mills, heat exposure can vary according to the size of the steel being rolled.

Plant No. 1

Plate Mills

Data were collected in three plate mills of this plant, designated on the maps as Building Nos. 3, 1, and 2, respectively. Most data were obtained in Building 1. Approximate dates of opening for the buildings are:

Building 3--1900
Building 1--1936
Building 2--1942

In Building 1, four furnaces are usually operating. When only three are running, heat exposure in the furnace area is reduced. Also in this building, fans in the charger pulpit were introduced only several years ago.

Plant No. 2

Hot Strip Rolling

The job of interest is the slab shearman. When plate steel is being rolled, he sits in an open platform working levers. Heat exposure may be high when steel is passing.

When steel for coiling is being rolled, this man becomes the crew leader for that process. This involves supervising the rolling and coil handling processes.

It has been reported that the hot strip building may have been hotter in the past when more coil was being produced and three work shifts were scheduled each day. These changes were said to have occurred after 1970.

Plant No. 7

Hot Strip Rolling

The job of interest is the coil bander. The rate of banding which is necessary changes from day-to-day.

Merchant Mill

The name "merchant mill" was given in the past to bar mills at which merchants selected bars for purchase. Most of these mills are known as bar mills today. Many different shapes of steel may be formed in these mills, by a series of passes of billets through rolls. Heat exposure

for each worker depends on his proximity to the hot steel and sizes and shapes of steel being rolled.

Plant No. 4

Four different buildings comprise the bar mill work area. Data were collected at one of these buildings. All mills are fairly similar, and date from approximately 1900.

Usually in this mill only 2 furnaces are operating now, although more often in the past three furnaces were running. It has also been stated that in this mill the furnace crew size decreased about 10 years ago. Thus, it is difficult to say for the heater and heater helper jobs in this mill whether exposure is now greater or less than in the distant past. However, in at least one mill other than the mill in which data were obtained, the heater helper works around the furnaces, not in a pulpit.

Plant No. 5

Data were collected at a mill which dates from 1905. Four other bar mills were closed in the 1930's while two mills were shut down about 1970. We received varying opinions as to whether these other mills were hotter than the mill in which study data were collected.

Open Hearth

Major open hearth steelmaking areas include a mixing area, a charging side, a pouring side, and a stripper building. In general, the mixer area consists of barrel-shaped hot-metal mixers which serve the purpose of storing molten iron from the blast furnaces until needed. In this process, separate casts of iron from the blast furnace are mixed, thus compensating for possible irregularities from cast-to-cast.

On the charging side, molten iron, scrap steel, limestone, and other elements are placed into each furnace until molten steel is formed. Overhead cranes and charging machines are utilized in this process. The furnace is then "tapped", with the steel flowing into ladles placed in the pit area. The ladles are then lifted by overhead cranes to the teeming or pouring platform, where, with the assistance of several workers, the steel is poured into molds of various types, depending on the type of steel or ingots desired. (One type of mold is described as hot-topped. These molds are prepared before pouring in an area away from the pouring platform.)

After the steel cools and solidifies, the ingots are separated from the molds in a stripping area. This is done by an overhead crane.

Heat exposure can be intense for workers who are involved in the tapping or pouring processes. However, exposure can be high at times for most workers in the open hearth. Some jobs in the area are quite strenuous at times, while others are rather sedentary.

It would be necessary to weigh many factors in considering direction of

change over time for each job in terms of heat exposure and work load. For the plants in this study, there have been changes in: cycle time, tapping time (probably), number of personnel, number of cranes and charging machines, number of furnaces, types of equipment, building architectural changes, and clothing (Aluminized reflective clothing was introduced about 1950). Each job of interest in the study in the open hearth has been affected over time by changes in at least one of these factors.

Plant No. 1

Eleven furnaces exist at present in the open hearth area although no more than 10 furnaces are in operation at any one time.

Tap-to-tap cycle time for each furnace is approximately 7-8 hours. Tap time for each furnace is approximately 20-25 minutes. Average pouring time on the pouring platform is approximately 45 minutes. However, pouring time can vary, depending on the type of mold being used. During WW II, several open hearth areas were in operation at this plant. In these sites the furnaces were smaller and cycle time was 16-18 hours. Also, in one or more of these areas, furnaces were on both sides of the teeming platform.

Plant No. 2

At present, six open hearth furnaces exist in the area, although no more than five of these are used at any one time. Cycle time generally ranges from 5-7 hours. Present tapping and pouring times are similar to those for Plant 1.

Before 1940, it is said that cycle time was 16-18 hours. From sometime in the 1940's to 1952, there were 9 open hearth furnaces in operation, at different sites than the present-day facility. In one area, there were 5 furnaces with an 8 hour cycle time. In another area, there were 4 furnaces with a 10-hour cycle time. From 1952 till sometime in the 1960's there were 11 furnaces available with an 8-9 hour cycle time.

Power and Fuel

The power and fuel division of a steel plant generally is responsible for supplying power where and when it is needed, utilizing various primary and by-product fuels. More important primary fuels are coal, fuel oil, natural gas, and purchased electric power. By-product fuels can include blast-furnace gas, coke-oven gas, pitch-tar, and coke breeze. These fuels are used to produce steam, which drives blowers, pumps, and electric generators, and may also be used for heating of furnaces.

In general, jobs in a power and fuel division are not strenous, and heat exposure is not intense, except for small intervals. In fact, many work locations are cool or cold in winter, even though power and fuel jobs of interest in this study were in enclosed buildings.

Plant No. 1

Measurements for this study were taken in two buildings. It is said that Building No. 1 probably was hotter in the past, when there was less ventilation and 12 boilers were operating, in contrast to six or eight boilers operating today. Four of the 12 older boilers were coal boilers, which apparently resulted in smoky conditions.

No changes over time were noted for Building No. 2.

Plant No. 4

Measurements and activity data at this plant were collected in an engine room of a rolling mill. An engineer works in this room operating a steam engine, a source of power for the mill. Two engineers used to do this job in the past, until an undetermined year.

Engineers at Plant 4 can work at several locations including engine rooms of three other rolling mills. Until recently, engineers were needed at the blast furnaces of this plant.

At least one worker's opinion is that the engine rooms at two of the four rolling mills may be hotter than the engine room where study data were collected.

Plant No. 5

Data were collected at this plant in a boiler house. No changes over time were noted, possibly due to the limited number of visits we were permitted to this building.

Plant No. 6

Five power and fuel buildings were of initial interest at this plant, although data were not collected at one of these buildings, due to extensive changes over time. Locations of workers in jobs of interest and building shutdowns resulted in the collection of most study data at Building No. 1. No extensive changes over time in general architecture or environment were noted in three of the four buildings in which data were collected. In the remaining one of these four buildings (Building No. 4) it was probably cooler when study data were collected than it was in past years. However, only one job (pump tender) of interest required the worker to visit this building, for very small periods of time.

Table 1

Changes Over Time for Surveyed Jobs

Work Area	Plant No.	Job Title	Furnace Size		No. of Furnaces		Cycle Time		Cast or Tap Time		Crew Size		Incentive	Protective Clothing	Modern Technology	Other Changes	Likely Net Effect on:	
			Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.					Environmental Heat Load	Metabolic Heat Load
Annealing	7	Annealer															None	None
		Assistant Annealer	NC				NA		NA				1940	None	None	BR (c. 1970)	None	None
		Hooker															Increase	None
		Craneman															Increase	None
Billet, Bloom, and Slab	1	Craneman	NA		NA		NA		NA					FRC	None	None	None	None
	2	Stamper	NA		NA		NA		NA					FRC	None	RHS (c. 1960)	Decrease	None
	5	Stamper	NA		NA		NA		NA					FRC	None	Fan (c. 1974)	Small Decrease	None
Blast Furnace	1	First Helper	X		NA		X				X		X	ARC (c. 1950)	BRM, ATD (c. 1960)	None	Decrease	Decrease
		Keeper															Decrease	Decrease
		Hot Blastman															None	Decrease
	2	First Helper	X		NA		X				X		X	ARC	Tractors	None	Decrease	Decrease
		Keeper															Decrease	Decrease
		Hot Blastman															None	Decrease
	5	Cinder Snapper	X		NA		X				X		X	ARC	Tractors	Larger Runners	Decrease	Decrease
		First Helper															Decrease	Decrease
		Keeper															Decrease	Decrease
		Hot Blastman															None	Decrease
	6	Cinder Snapper	X		NA		X				X		1959	ARC	BRM (c. 1960) ATD (c. 1960)	OC (c. 1942)	Decrease	Decrease
		First Helper															Decrease	Decrease
		Keeper															Decrease	Decrease
		Hot Blastman															None	Decrease
Coke Plant	2	Heater	NA		NA		NC		NA		X		X	FRC	None SC	MTPC LTT	Increase	Increase
		Heater Helper															Increase	Increase
		Lidman															Decrease	Decrease
	4	Door Machine Operator	NA		NA		NC		NC		X		X	FRC	PT (1964) SC	MTPC LTT	None	Decrease
		Heater							NA								Increase	Increase
		Heater Helper															Increase	Increase
		Lidman															Decrease	Decrease
		Quenching Car Operator					NC		NC								None	None

See Legend following Table

Table 1(Continued)

Changes Over Time for Surveyed Jobs

Work Area	Plant No.	Job Title	Furnace Size Inc.	Furnace Size Dec.	No. of Furnaces Inc.	No. of Furnaces Dec.	Cycle Time Inc.	Cycle Time Dec.	Cast or Tap Time Inc.	Cast or Tap Time Dec.	Crew Size Inc.	Crew Size Dec.	Incentive	Protective Clothing	Modern Technology	Other Changes	Likely Net Effect on: Environmental Heat Load	Likely Net Effect on: Metabolic Heat Load
Electric Furnace	3	First Helper												ARC	O_2,		Decrease	Decrease
		Second Helper				NC							X	FRC	Tractors	None	Decrease	Decrease
		Third Helper															Decrease	Decrease
	5	First Helper															Decrease	Decrease
		Second Helper				c. 1960							c. 1960	ARC	O_2,	RF	Decrease	Decrease
		Third Helper												FRC	Tractors		Decrease	Decrease
Foundry	6	Chipper											1975	None		None	None	None
		Ladle Liner												FRC		Larger Ladles	None	Increase
		First Closer										NC				Bigger Molds	Decrease	None
		Second Closer	NA		NA		NA					X	1967	ARC		Faster Pouring	Decrease	None
		Closer Helper										X				No Fe Troughs	Decrease	None
Hot Strip Rolling	2	Slab Shearman	NA		NA		NA		NA					FRC	None	Less busy (1970)	Small Decrease	None
	7	Coil Bander	NA		NA		NA		NA				X	FRC	PT	None	None	Decrease
Merchant Mill	4	Heater												FRC				
		Heater Helper	NC		X		NA		NA		c. 1965		X		None	None		
		Leverman												None				
		Guide Setter																
	5	Heater																Decrease
		Heater Helper					NA		NA				c. 1950		AC	None		Decrease
		Finisher																
		Bougher																

See Legend following Table

Table 1 (Continued)

Changes Over Time for Surveyed Jobs

Work Area	Plant No.	Job Title	Furnace Size		No. of Furnaces		Cycle Time		Cast or Tap Time		Crew Size		Incentive	Protective Clothing	Modern Technology	Other Changes	Likely Net Effect on: Environmental Heat Load	Likely Net Effect on: Metabolic Heat Load
			Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.						
Open Hearth	1	Mixer Operator	NC		NC		NC		NC		NC				AIC (c. 1952)		Decrease	None
		Hot Metal Craneman													AIC (1960)			
		Charging Machine Operator	X		NC		X				(NC)							
		First Helper											X		O_2			Decrease
		Second Helper												ARC (c. 1948)	Tractors & Dolomite Machines			Decrease
		Third Helper																Decrease
		Ladle Craneman													AIC (c. 1955)			
		First Steel Pourer													AP			
		Platform Man												ARC (c. 1948)				
	2	Mixing Craneman	NC		NC		NC		NC		NC			FRC	None	None	None	None
		Hot Metal Craneman									X				AIC (1951)	None	Decrease*	
		Charging Machine Operator									X							
		First Helper													O_2,			Decrease
		Second Helper	X		X		X				(NC)		X	ARC (c. 1953)	Tractors & Dolomite Machines			Decrease
		Third Helper																Decrease
		Ladle Craneman																
		First Steel Pourer							X					ARC (c. 1953)	AP (c. 1957)	Longer Pouring Time but Fewer Pours		
		Hot Top Liner	NA		NA		NA		NA						None	None	None	None
		Stripper Craneman	NA		NA		NA		NA						AIC (1951)		Decrease	None

See Legend following Table

Table 1(Continued)

Changes Over Time for Surveyed Jobs

Work Area	Plant No.	Job Title	Furnace Size Inc.	Furnace Size Dec.	No. of Furnaces Inc.	No. of Furnaces Dec.	Cycle Time Inc.	Cycle Time Dec.	Cast or Tap Time Inc.	Cast or Tap Time Dec.	Crew Size Inc.	Crew Size Dec.	Incentive	Protective Clothing	Modern Technology	Other Changes	Likely Net Effect on: Environmental Heat Load	Likely Net Effect on: Metabolic Heat Load
Plate Mill	1	Charger		NC		NC								FRC	None	Fan (c. 1970)	None	None
		Heater														None	None	None
		Hooker															None	None
		Layout man															None	None
		Marker "															None	None
		Plate Shearman		NA		NA		NA		NA			X	None	None	None	None	None
		Salt man															None	None
		Scrapman															None	None
		Stamper															None	None
Power and Fuel	1	Fireman															None	None
		Oiler			X								X				None	None
		Water Tender															None	None
	4	Engineer									X						Increase	Increase
	5	Boiler Clean.															None	None
		Boiler Repair.															None	None
		Flue Cleaner						NA		NA			X				None	None
		Water Tender															None	None
	6	Engineer															None	None
		Fireman															None	None
		Pump Tender									NC		1972				None	None
		Water Tender																

See Legend following Table

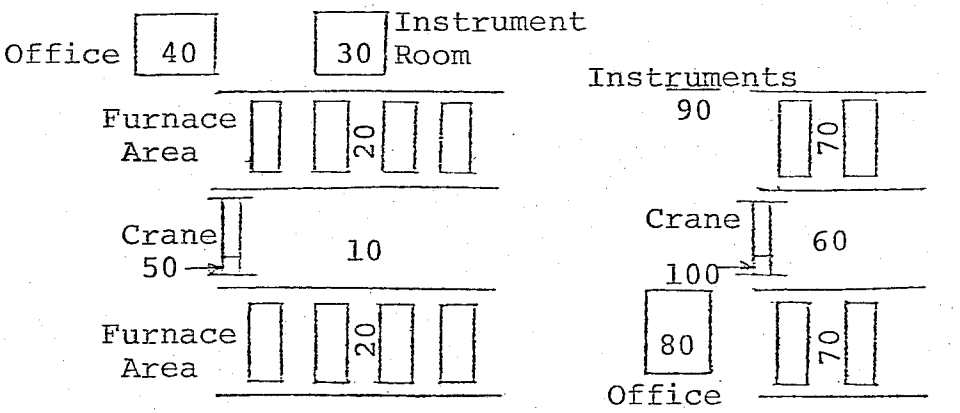
Legend for Table 1

Entry	Meaning
Blank	Not known
NC	No change
X	No date available
NA	Not applicable
BRM	Better runner materials
ATD	Automated tap-hole drill
AC	Automatic controls
ARC	Aluminized reflective clothing
OC	Overhead cranes
PT	Pneumatic tools
RHS	Radiant heat shield
BR	Building remodeled
MTPC	More tasks due to pollution control
LTT	Less time topside
SC	Smokeless charging
RF	Roof ventilation
FRC	Flame retardent clothing
AIC	Air conditioning
AP	Automatic power
*	But readings taken with air conditioning off
O_2	Oxygen to heat furnace
Fe	Iron

Figure 1

WORK AREA: ANNEALING

Plant No.: 7



20, 70: General Furnace Area

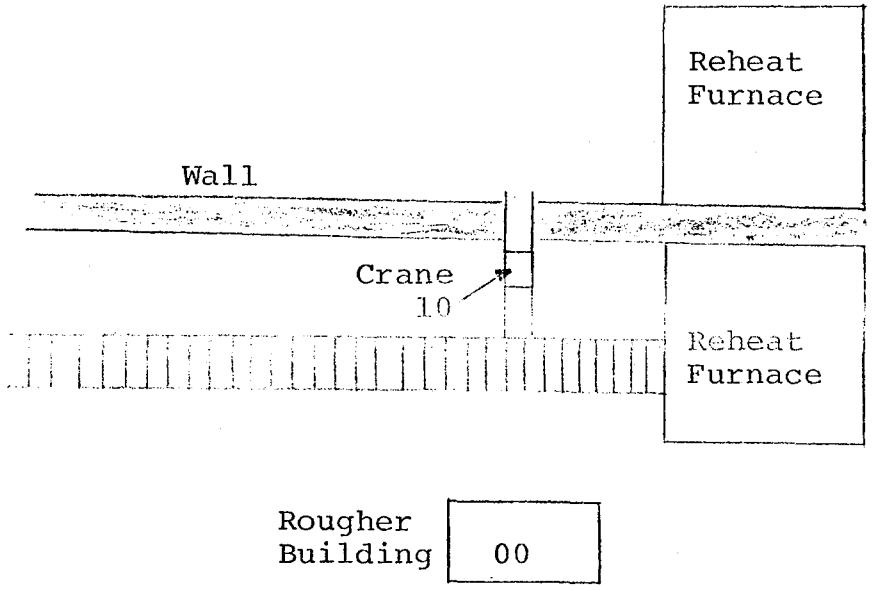
21, 71: Area with Furnace in Air

	Location Numbers
Group 1	All

Figure 2

WORK AREA: BILLET, BLOOM, AND SLAB MILLS

Plant No.: 1

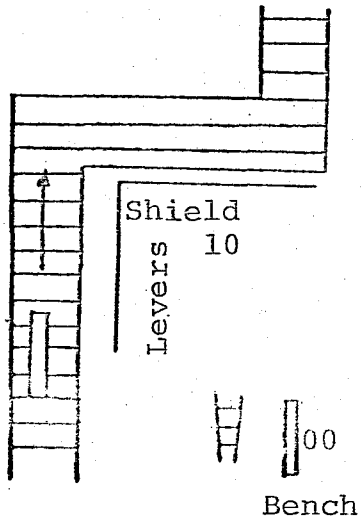


	Location Numbers
Group 1	All

Figure 3

WORK AREA: BILLET, BLOOM, AND SLAB MILLS

Plant No.: 2

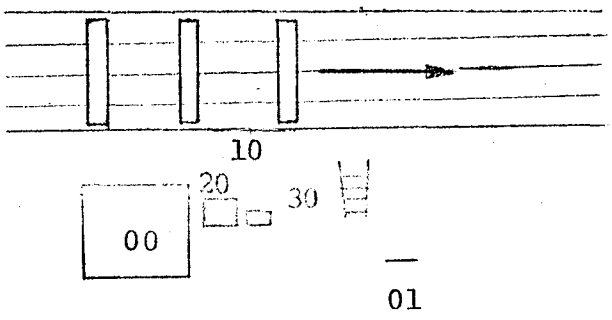


	Location Numbers
Group 1	All

Figure 4

WORK AREA: BILLET, BLOOM, AND SLAB MILLS

Plant No.: 5



10, 20, 30: Steel not Passing

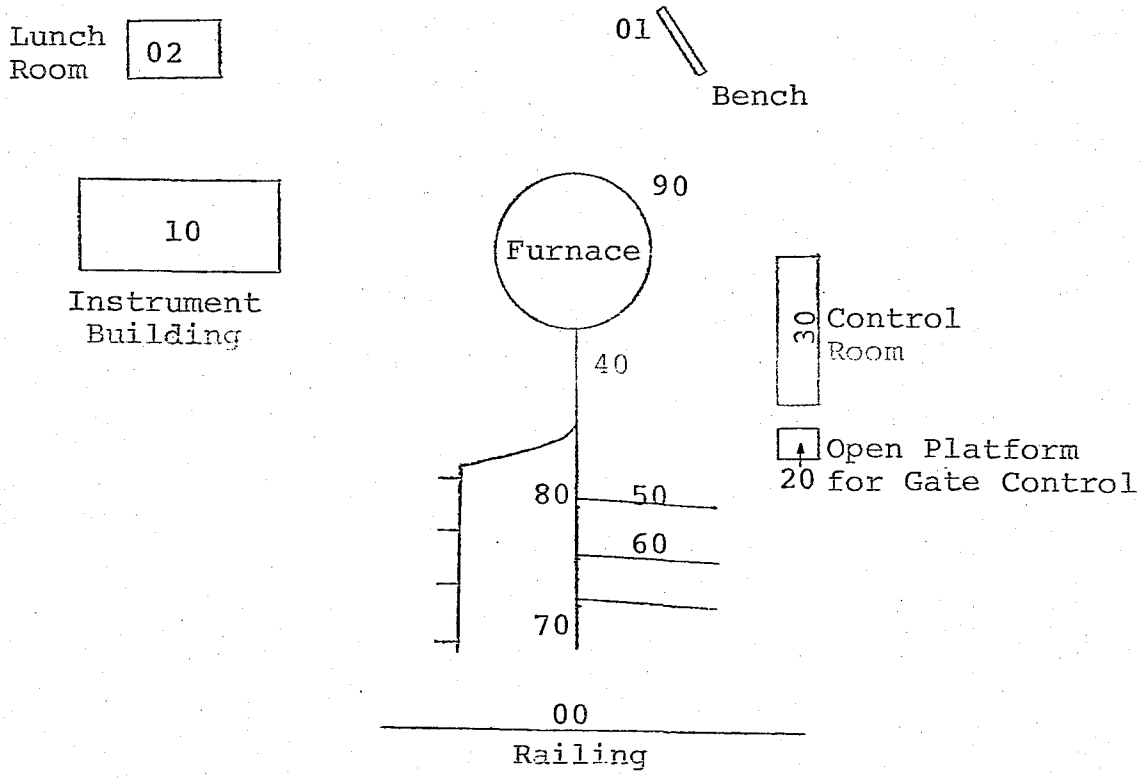
11, 21, 31: Steel Passing

	Location Numbers
Group 1	11, 21, 31
Group 2	0, 1, 10, 20, 30

Figure 5

WORK AREA: BLAST FURNACE

Plant No.: 1



FINAL DIGIT OF EACH LOCATION NUMBER:

0: Before Cast

1: During Cast

2: After Cast

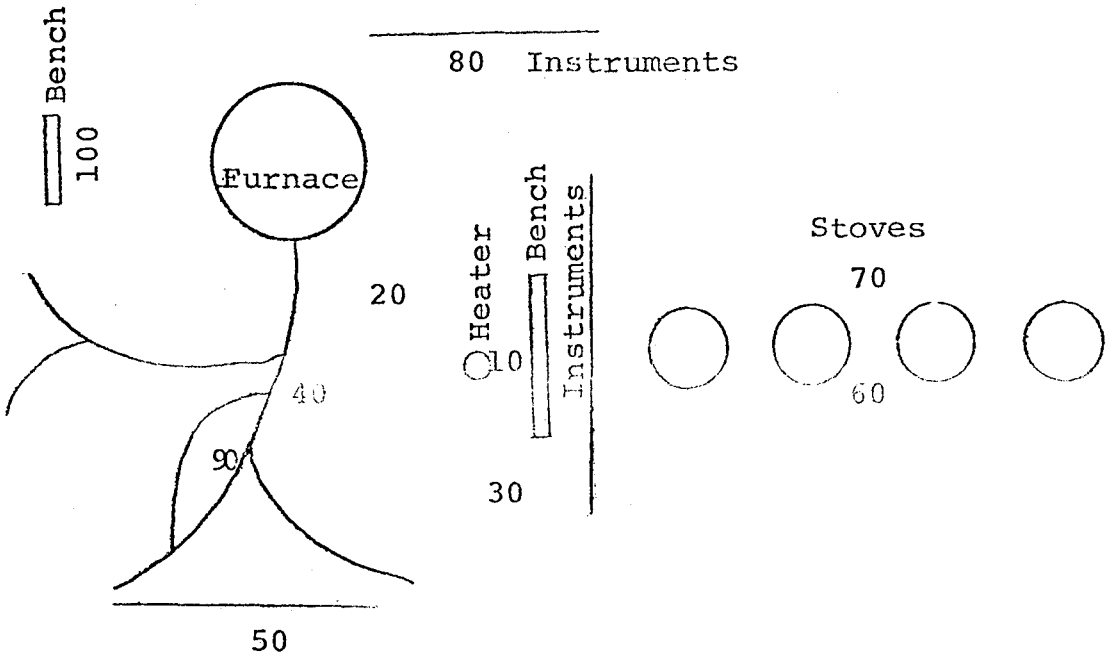
	Location Numbers
Group 1	40-42, 50-52, 60-62, 70-72, 80-82
Group 2	0, 1, 2, 10, 20-22, 30-32, 90, 92, 100, 102

Figure 6

WORK AREA: BLAST FURNACE

Plant No.: 2

Furnace No.: 1



FINAL DIGIT OF EACH LOCATION NUMBER:

0: Before Cast

1: During Cast

2: After Cast

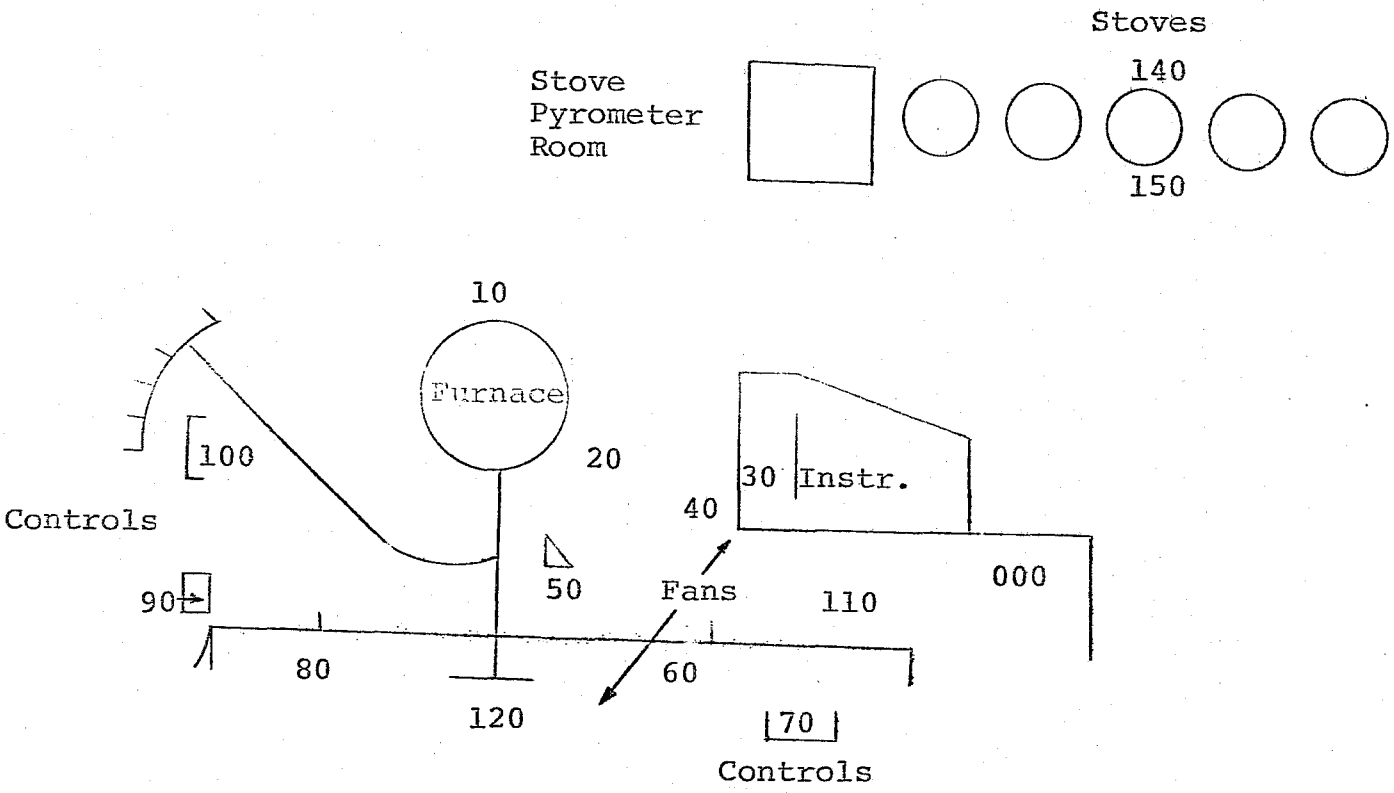
	Location Numbers
Group 1	20-22, 40-42, 90-92
Group 2	10-12, 30-32, 50-52, 60-62 70-72, 80-82, 100-102

Figure 7

WORK AREA: BLAST FURNACE

Plant No.: 2

Furnace No.: 2



FINAL DIGIT OF EACH LOCATION NUMBER:

0: Before Cast

1: During Cast

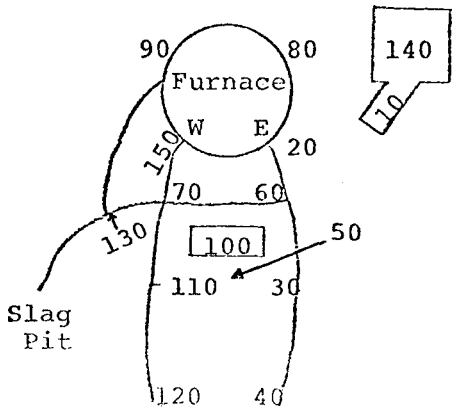
2: After Cast

	Location Numbers
Group 1	20-22, 40-42, 50-52
Group 2	10-12, 30-32, 60-62, 70-72, 80-82, 100-102, 110-112, 120-122, 130, 140, 150

Figure 8

WORK AREA: BLAST FURNACE

Plant No.: 5



FINAL DIGIT OF EACH LOCATION NUMBER:

0: Before Cast

1: During Cast

2: After Cast

IF CASTING IS ON:

East Side

Numbers Stay Same

West Side

70 = 20

150 = 60

110 = 30

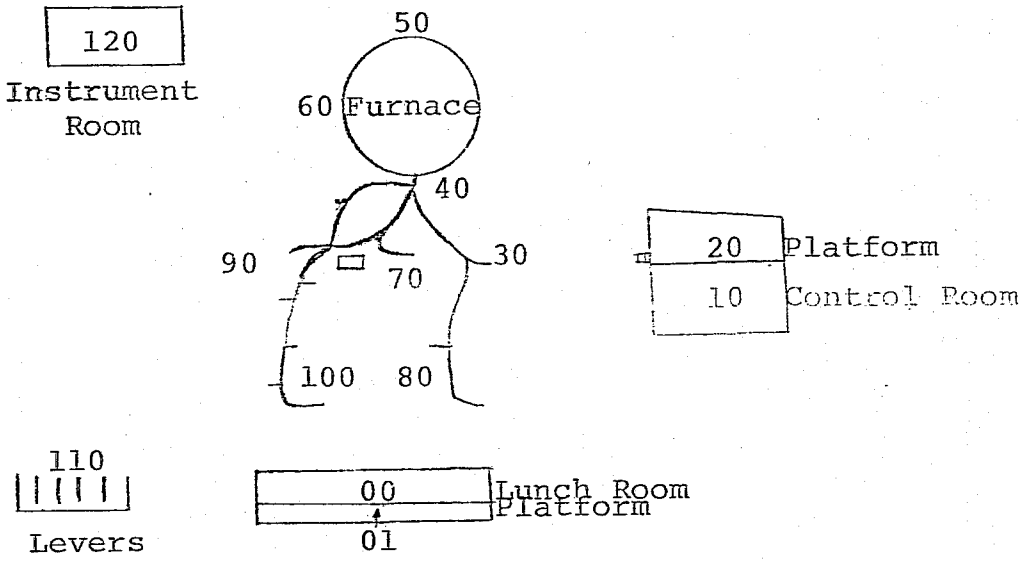
120 = 40

	Location Numbers
Group 1	20-22, 30-32, 60, 62
Group 2	10-12, 40-42, 50-52, 70, 72, 80, 82, 90, 92, 100, 110, 120, 130, 140-142, 150

Figure 9

WORK AREA: BLAST FURNACE

Plant No.: 6



FINAL DIGIT OF EACH LOCATION NUMBER:

0: Before Cast

1: During Cast

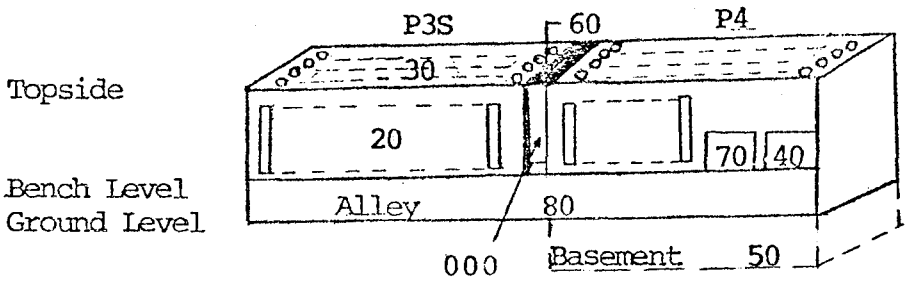
2: After Cast

	Location Numbers
Group 1	30-32, 40-42, 60, 62, 70-72, 90-92
Group 2	0, 1, 10-12, 20-22, 50, 52, 80-82, 100-102, 110-112, 120

Figure 10

WORK AREA: COKE PLANT

Plant No.: 2



40: Reversing Room

60: Rest Area

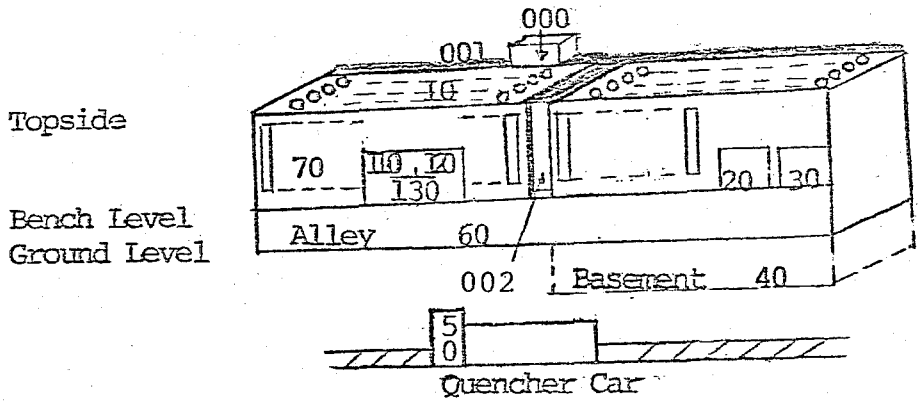
70: Coffee Area

	Location Numbers
Group 1	0, 40, 60, 70
Group 2	20, 30, 50, 80

Figure 11

WORK AREA: COKE PLANT

Plant No.: 4



000: Rest Shed

20: Rest Room

30: Reversing Room

110, 120, 130: No Door in Machine

111, 121, 131: Coke Being Pushed

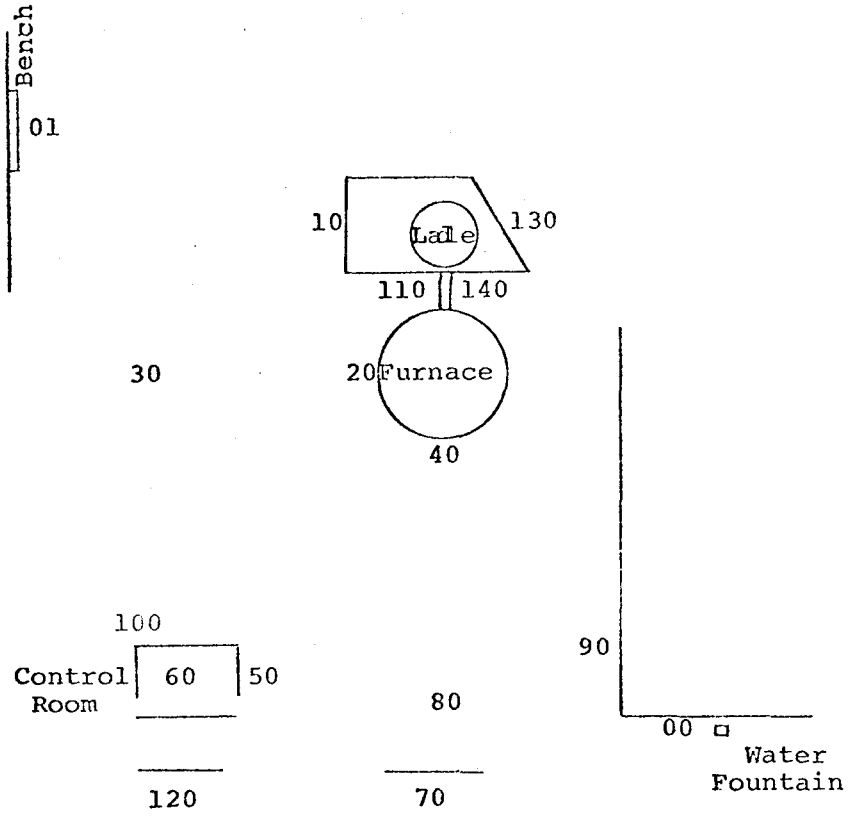
112, 122, 132: Oven Door in Machine
(Coke Not Being Pushed)

	Location Numbers
Group 1	0, 1, 2, 20, 30
Group 2	10, 40, 50, 60, 70, 110-112, 120-122, 130-132

Figure 12

WORK AREA: ELECTRIC FURNACE

Plant No.: 3



10, 110, 130, 140: Before Tap

11, 111, 131, 141: During Tap

12, 112, 132, 142: After Tap

FINAL DIGIT OF ALL OTHER LOCATIONS:

1: Electrodes Out and/or Furnace Door Open

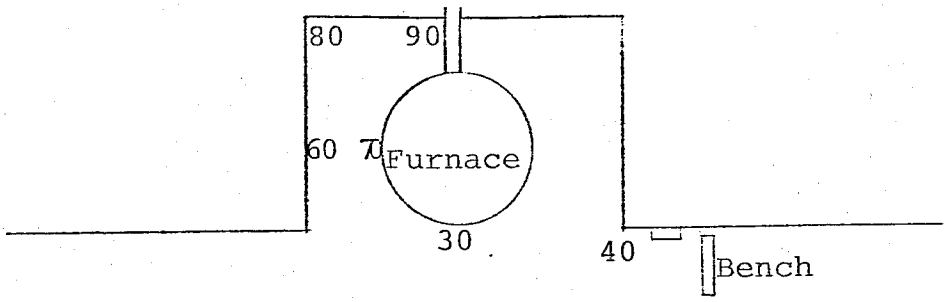
0: All Other Times

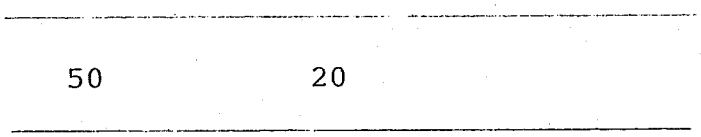
	Location Numbers
Group 1	10-12, 20-21, 40-41, 110-112, 130-132, 140, 142
Group 2	0, 1, 30-31, 50-51, 60-61, 70-71, 80-81, 90-91, 100-101, 120-121

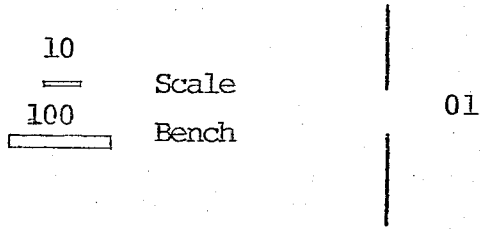
Figure 13

WORK AREA: ELECTRIC FURNACE

Plant No.: 5







10, 20, 30, 40, 50, 60, 70, 100: Door Closed and Electrodes In

11, 21, 31, 41, 51, 61, 71, 101: Door Open and/or Electrodes Out

80, 90: Before Tap

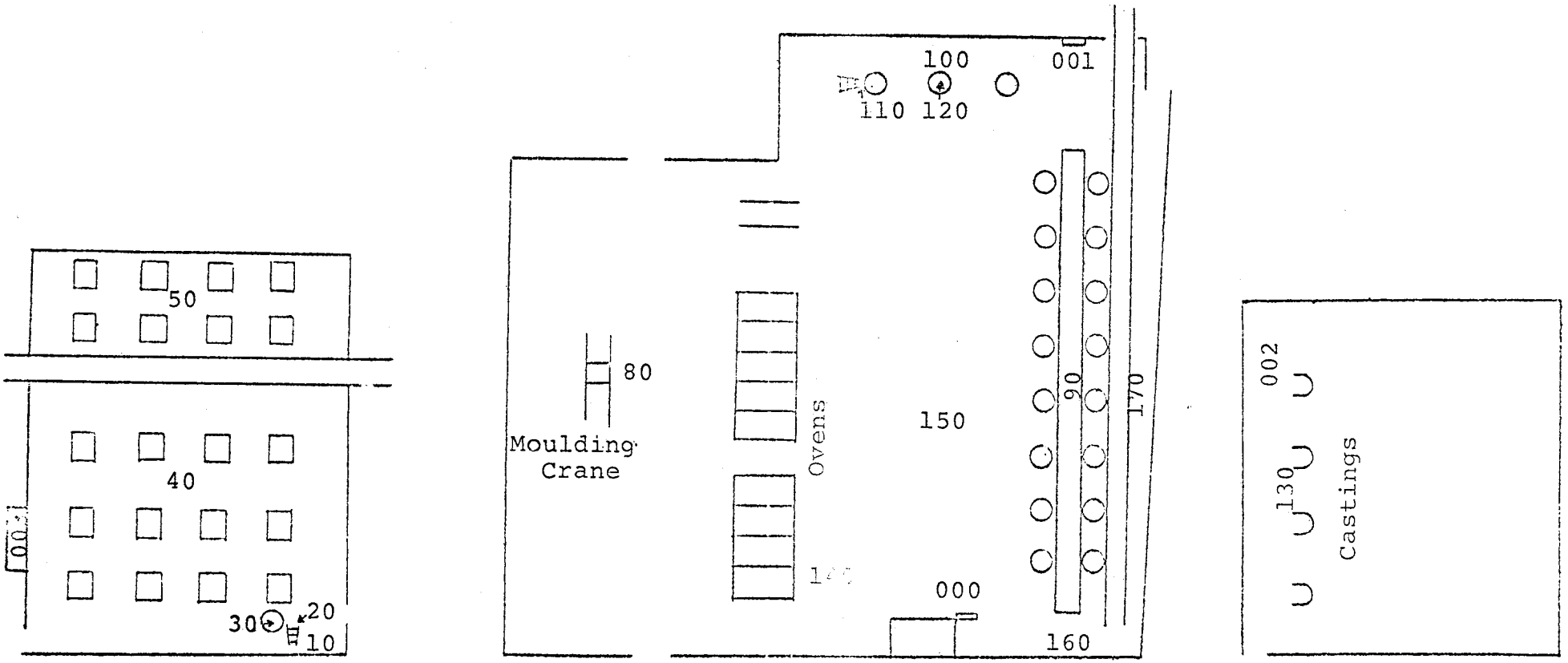
82, 92: After Tap

	Location Numbers
Group 1	30-31, 60-61, 70, 80-82
Group 2	0, 1, 10-11, 20-21, 40-41, 50-51, 90, 92, 100-101

Figure 14

WORK AREA: FOUNDRY

Plant No.: 6



40: No Tops
41: Tops On

90: Before Pouring
91: During Pouring

Building No. 1

Building No. 2

Building No. 3

A-30

Location Numbers

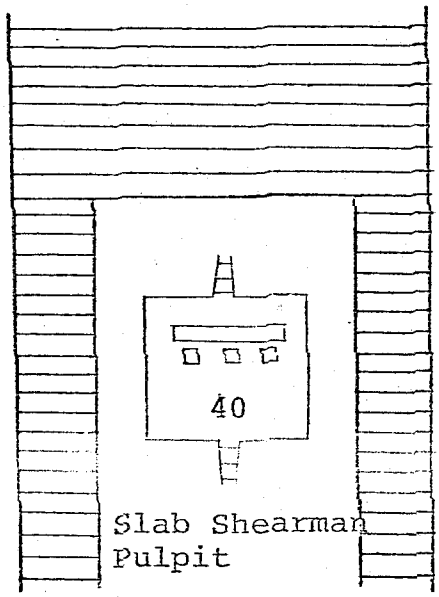
Group 1

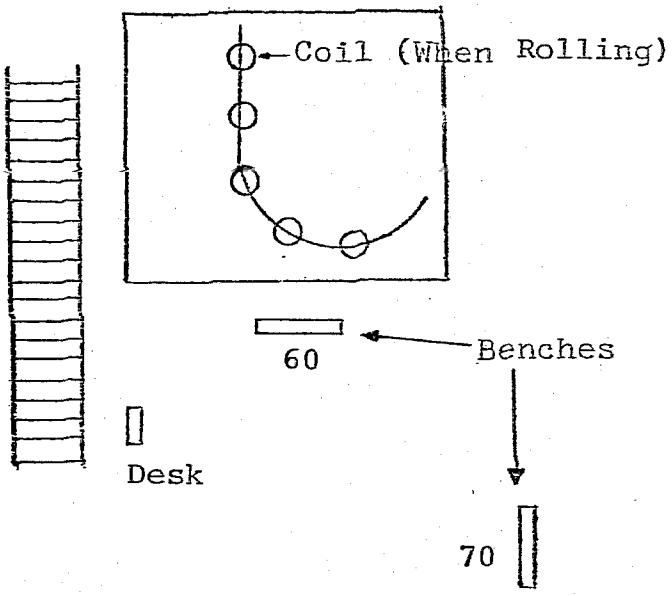
All

Figure 15

WORK AREA: HOT STRIP ROLLING

Plant No.: 2





60,70: Not Rolling Coil

61,71: Rolling Coil

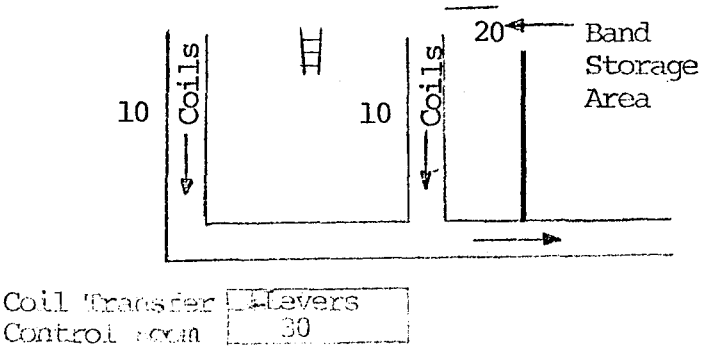
Location Numbers

All

Figure 16

WORK AREA: HOT STRIP ROLLING

Plant No.: 7



10: Coil Not Passing

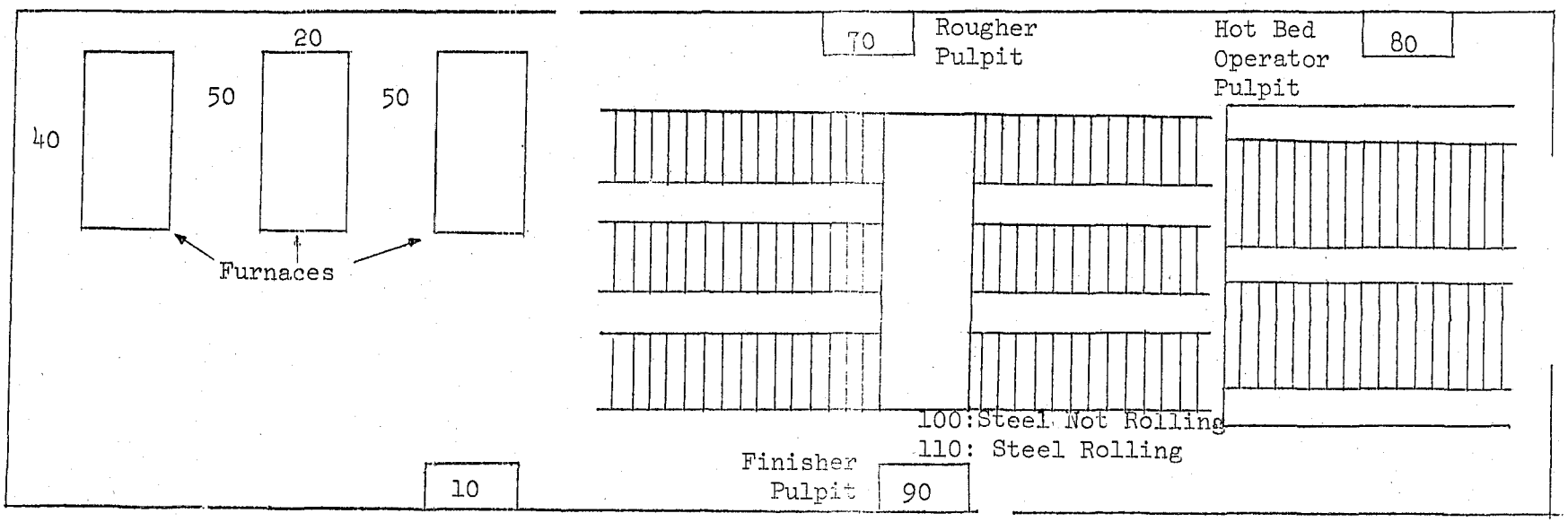
11: Coil Passing

	Location Numbers
Group 1	All

Figure 17

WORK AREA: MERCHANT MILL

Plant No.: 4

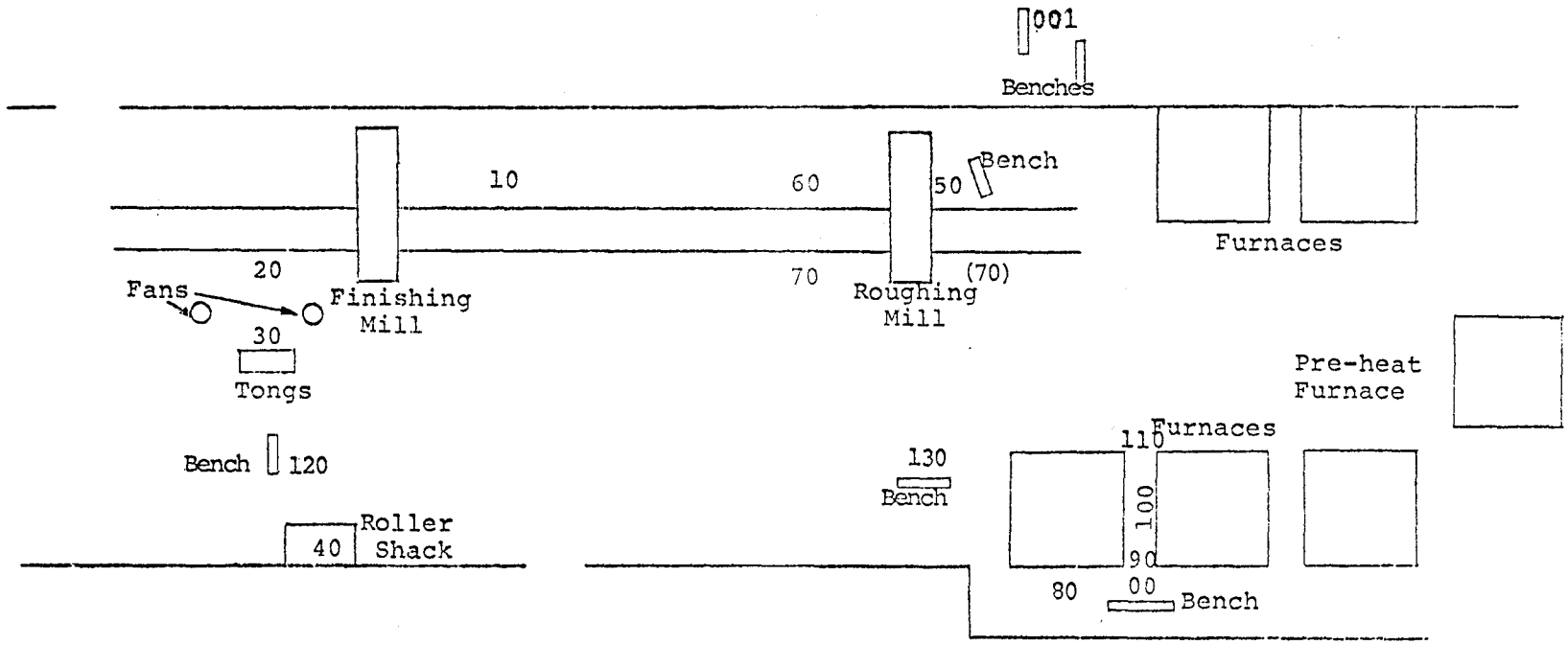


Group	Location Numbers
1	All

Figure 18

WORK AREA: MERCHANT MILL

Plant No.: 5



10, 20, 30, 50, 60, 70, 120, 130: Steel Not Passing

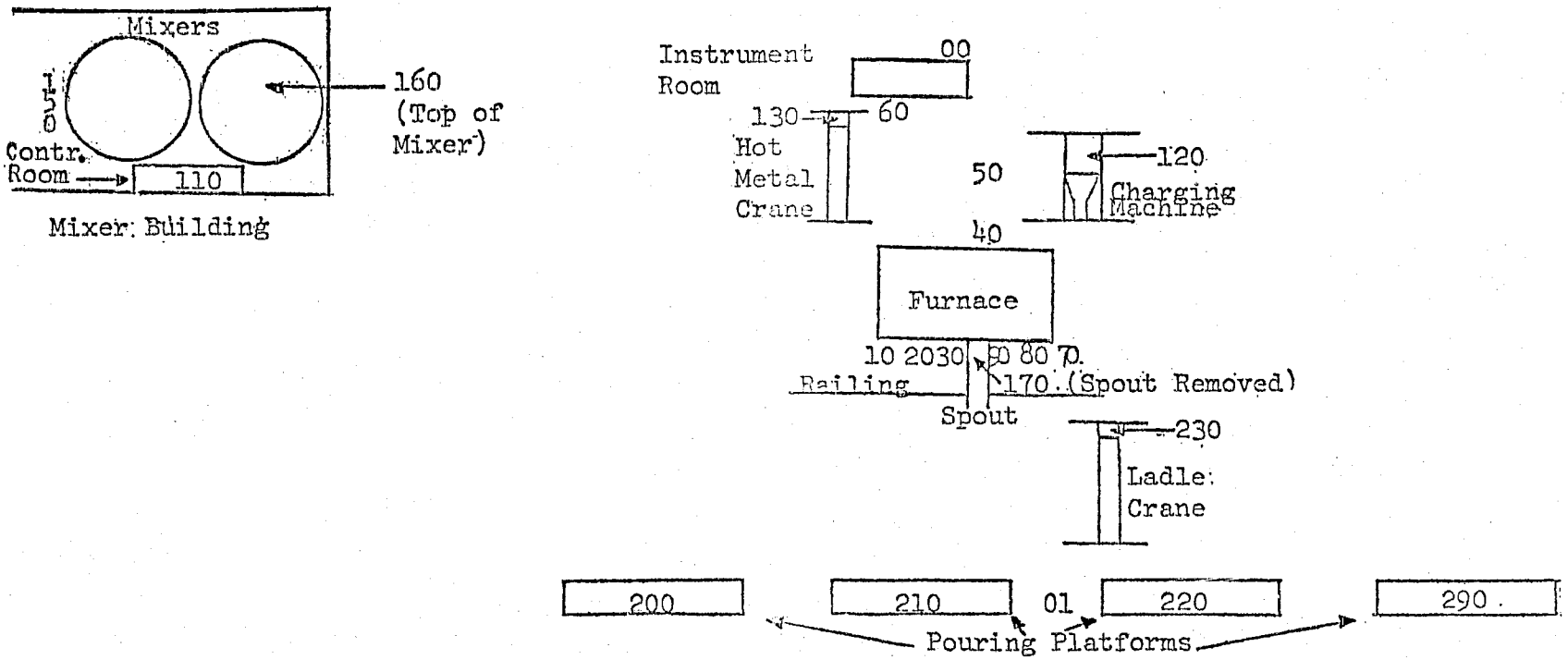
11, 21, 31, 51, 61, 71, 121, 131: Steel Passing

	Location Numbers
Group 1	0, 1, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130
Group 2	11, 21, 31, 51, 61, 71, 121, 131

Figure 19

WORK AREA: OPEN HEARTH

Plant No.: 1

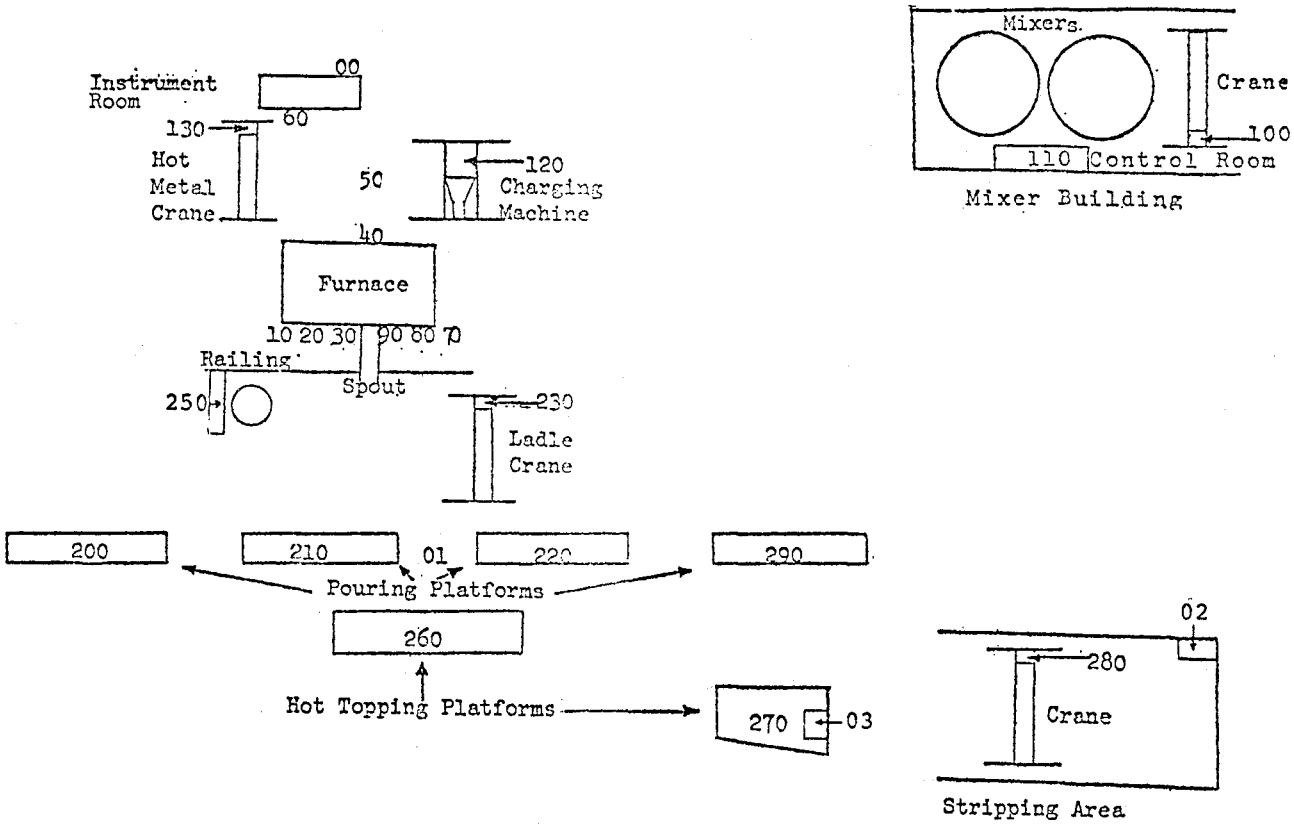


	Location Numbers
Group 1	10-12, 20-22, 30-32, 40-41, 70-72, 80-82, 90-92, 172, 201 211, 221, 291
Group 2	0, 1, 50-51, 60-61, 110-111, 120 130, 150, 160, 200, 210, 220, 230 290

Figure 20

WORK AREA: OPEN HEARTH

Plant No.: 2



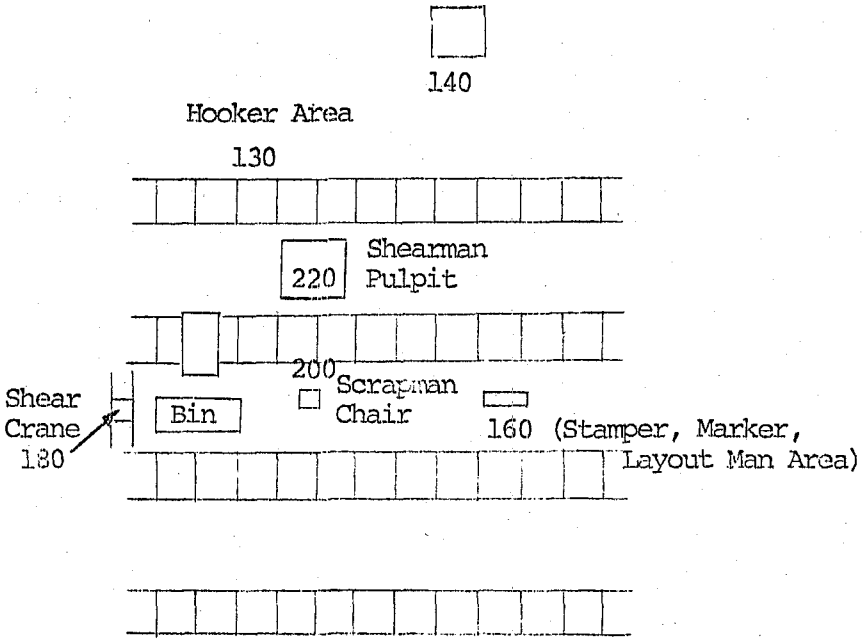
	Location Number
Group 1	10-12, 20-22, 30-32, 40-41, 70, 72, 80, 82, 90, 92, 201, 211, 221, 291
Group 2	0, 1, 2, 3, 50-51, 60-61, 100, 110, 120, 130, 200, 210, 220, 230, 250, 260, 270-271, 280, 290

Figure 21

WORK AREA: PLATE MILL

Plant No.: 1

Mill No.: 1



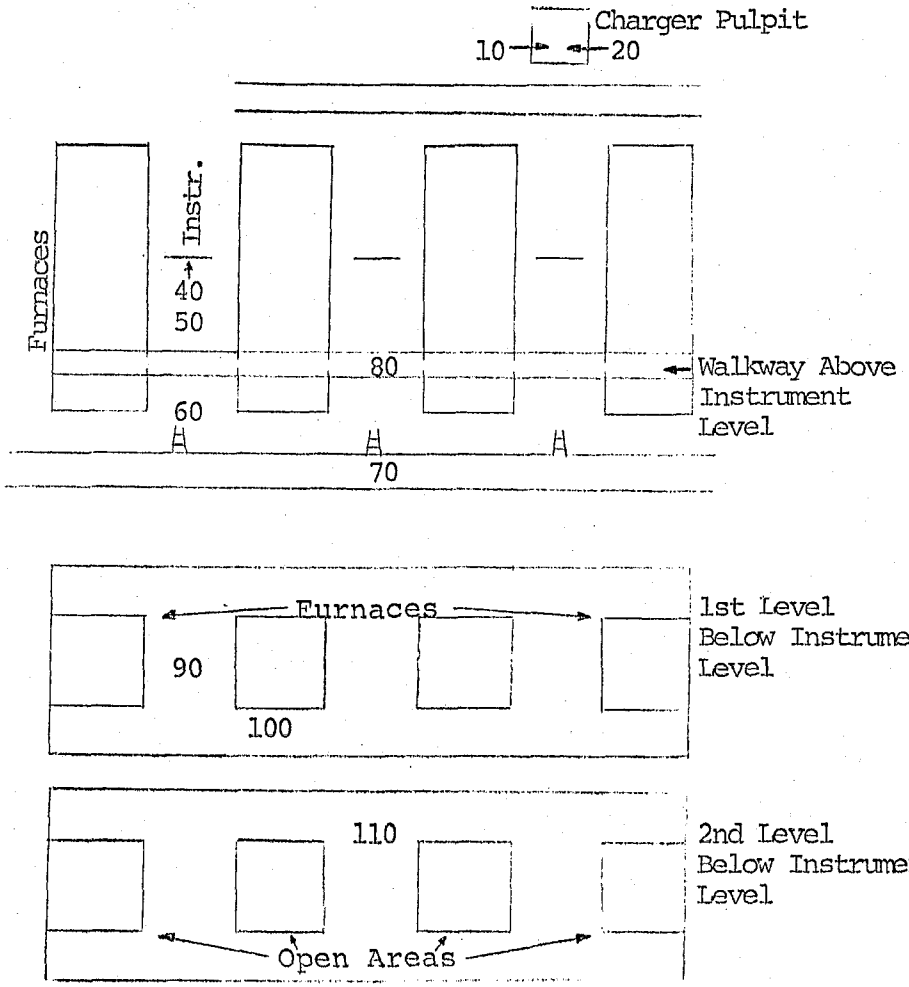


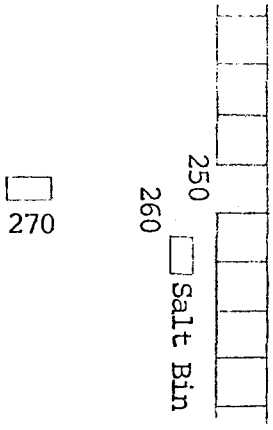
Figure 22

WORK AREA: PLATE MILL

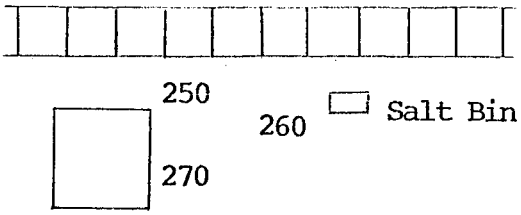
Plant No.: 1

Mill No.: 2

160 (Stamper, Marker, Layout Man Area)



Mill No.: 3



	Location Numbers
Group 1	10, 20, 40, 50, 60, 70, 80, 90, 100, 110
Group 2	130, 140, 160, 180, 200, 220
Group 3	250, 260, 270

Figure 23

WORK AREA: POWER AND FUEL

Plant No.: 1

Building No.: 1

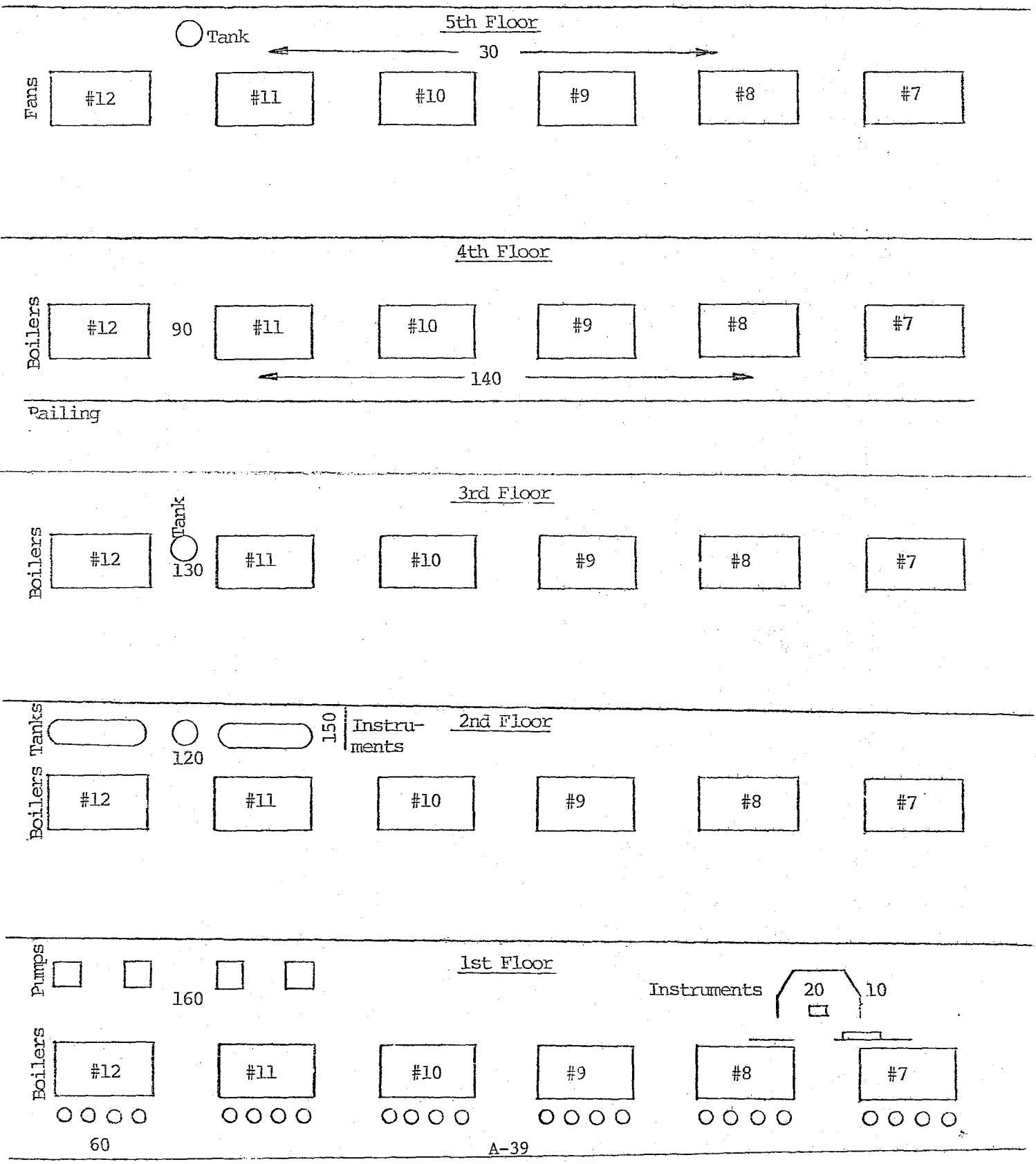
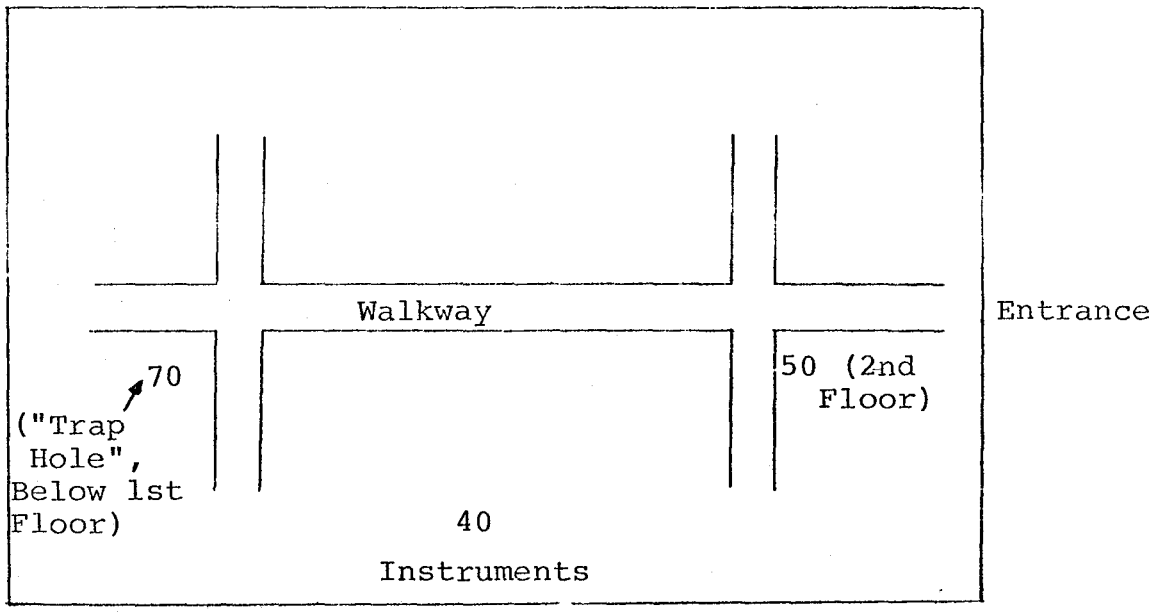


Figure 24

WORK AREA: POWER AND FUEL

Plant No.: 1

Building No.: 2

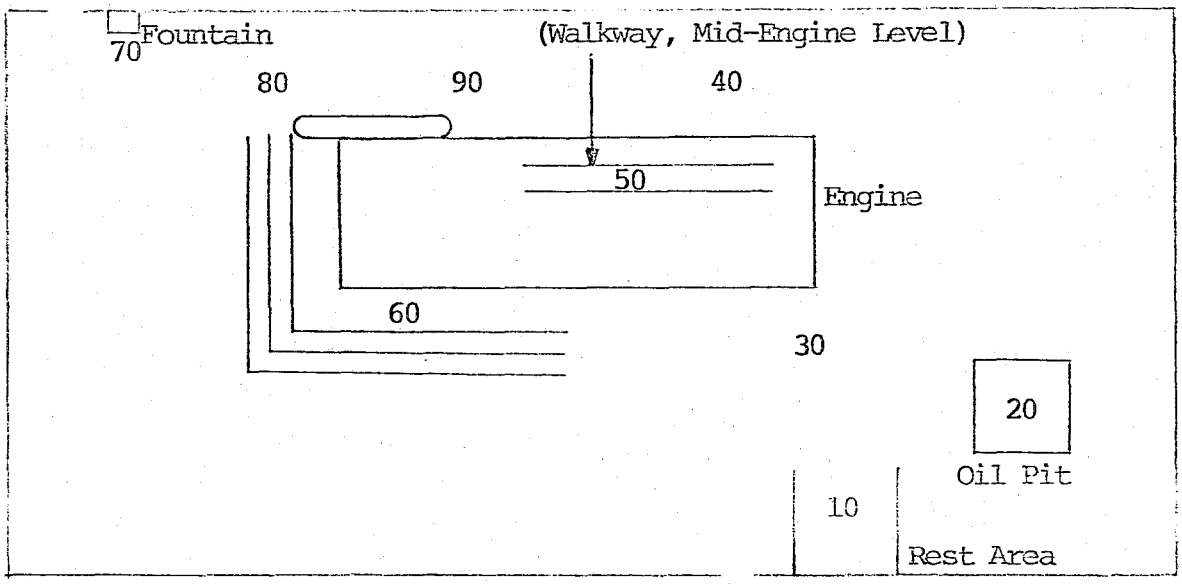


	Location Numbers
Group 1	All

Figure 25

WORK AREA: POWER AND FUEL

Plant No.: 4



FINAL DIGIT OF EACH LOCATION NUMBER:

0: Engine Off

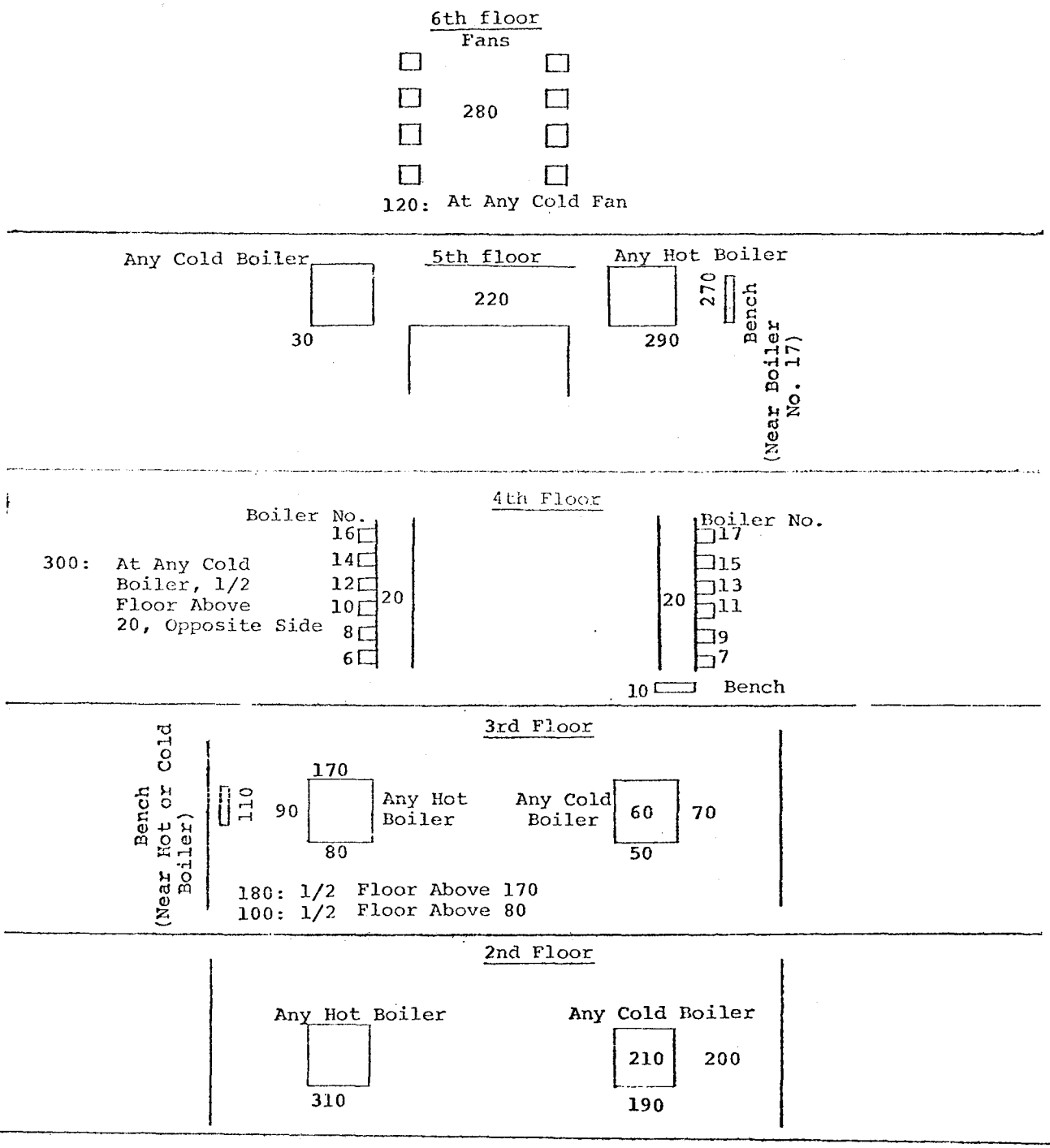
1: Engine On

	Location Numbers
Group 1	10, 20, 30, 40, 50, 60 70, 80, 90
Group 2	11, 21, 31, 41, 51, 61 71, 81, 91

Figure 26

WORK AREA: POWER AND FUEL

Plant No.: 5



Location Numbers

Group 1

All

WORK AREA: POWER AND FUEL

Plant No.: 6

Building No.: 1 (Floor No. 1)

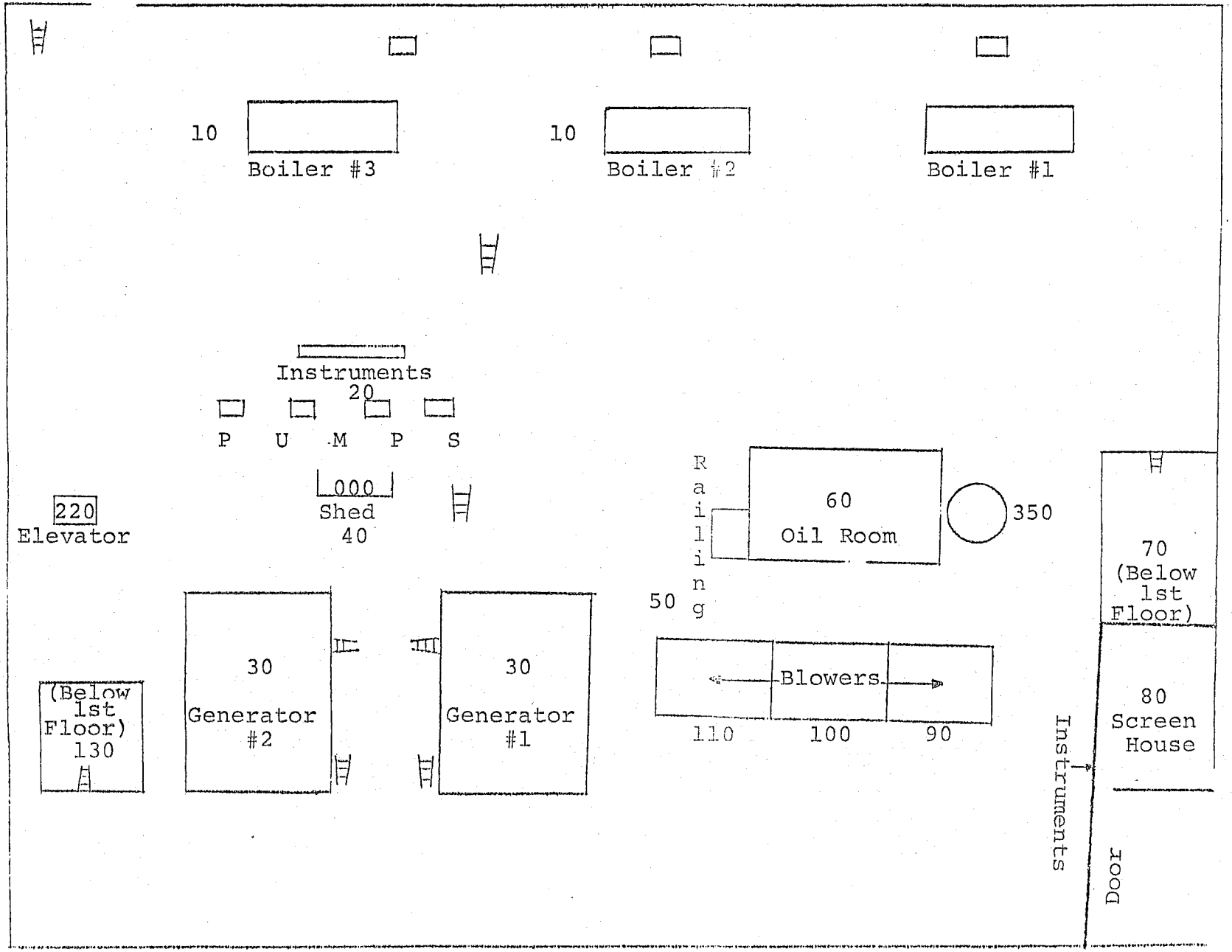


Figure 28

WORK AREA: POWER AND FUEL

Plant No.: 6

Building No.: 1 (Floor No. 2)

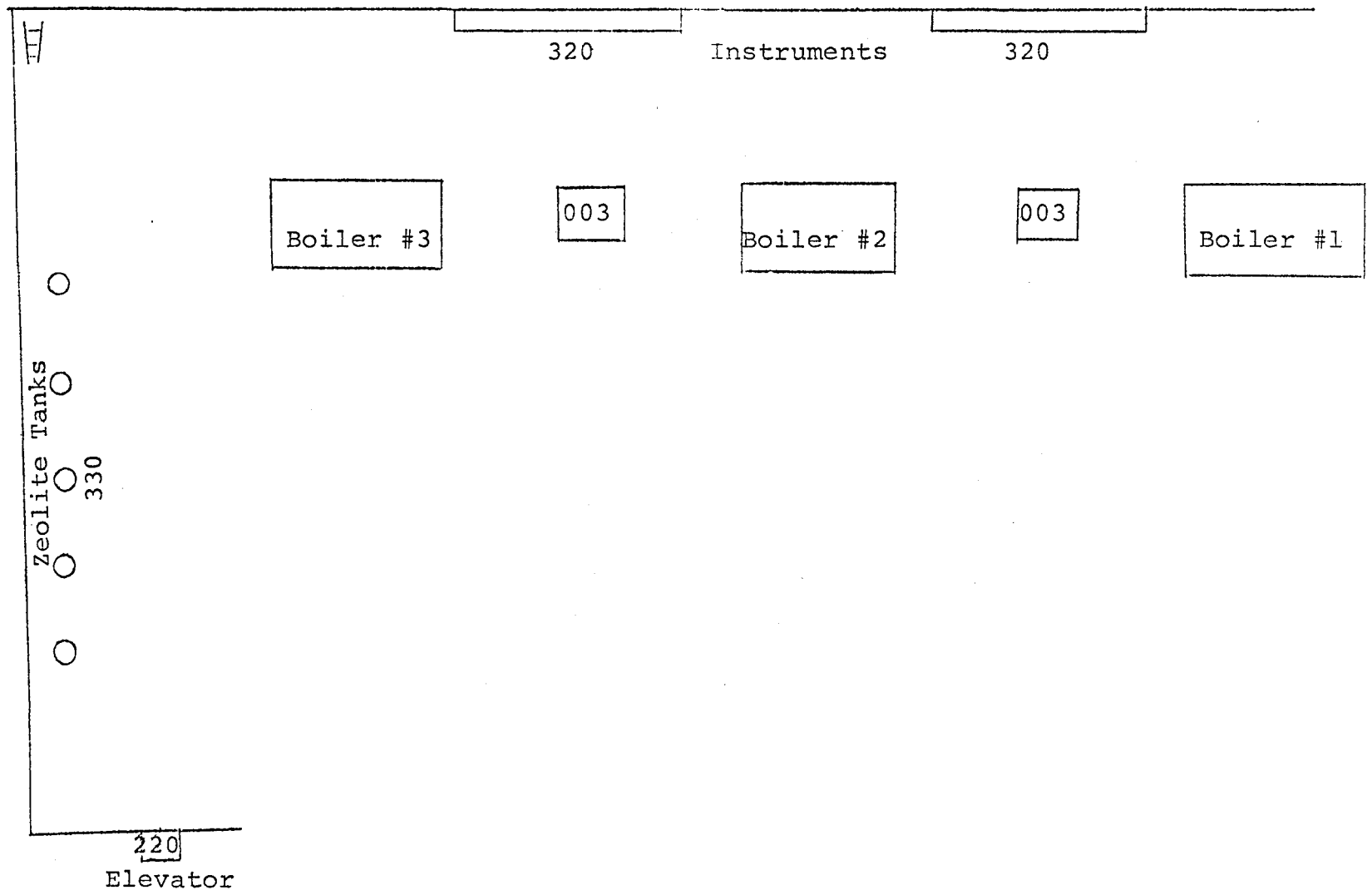


Figure 29
WORK AREA: POWER AND FUEL

Plant No.: 6

Building No.: 1 (Floor No. 3)

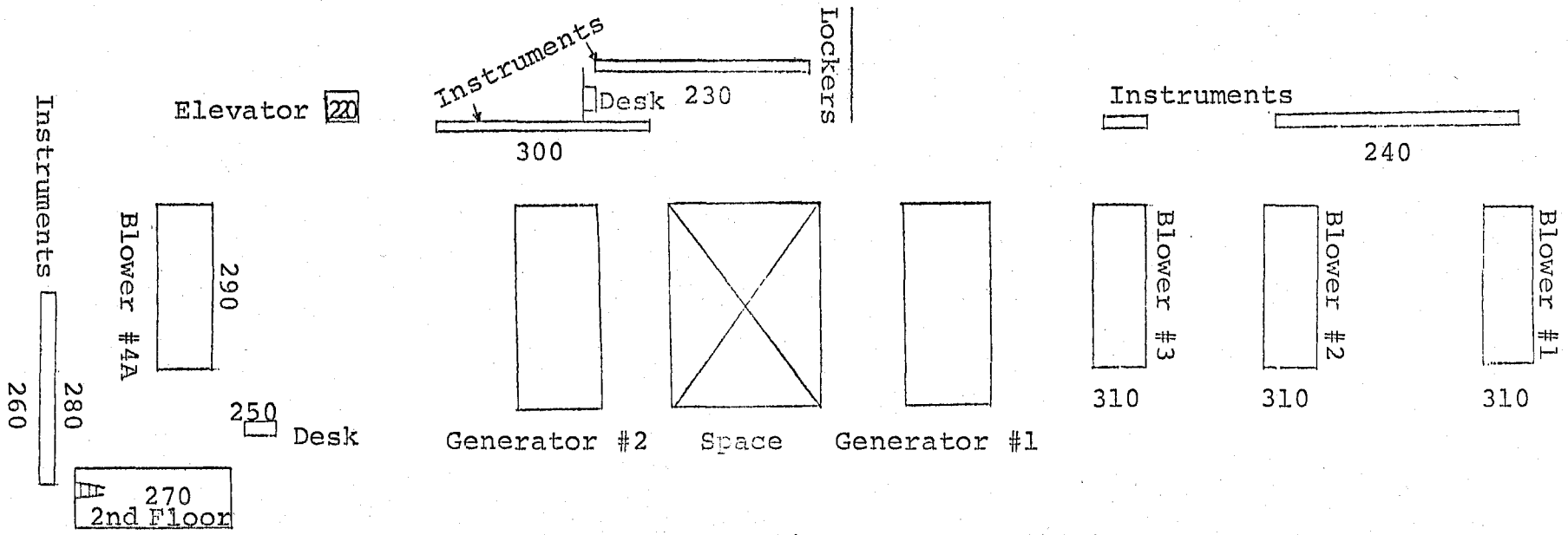


Figure 30

WORK AREA: POWER AND FUEL

Plant No.: 6

Building No.: 1 (Floor No. 6)

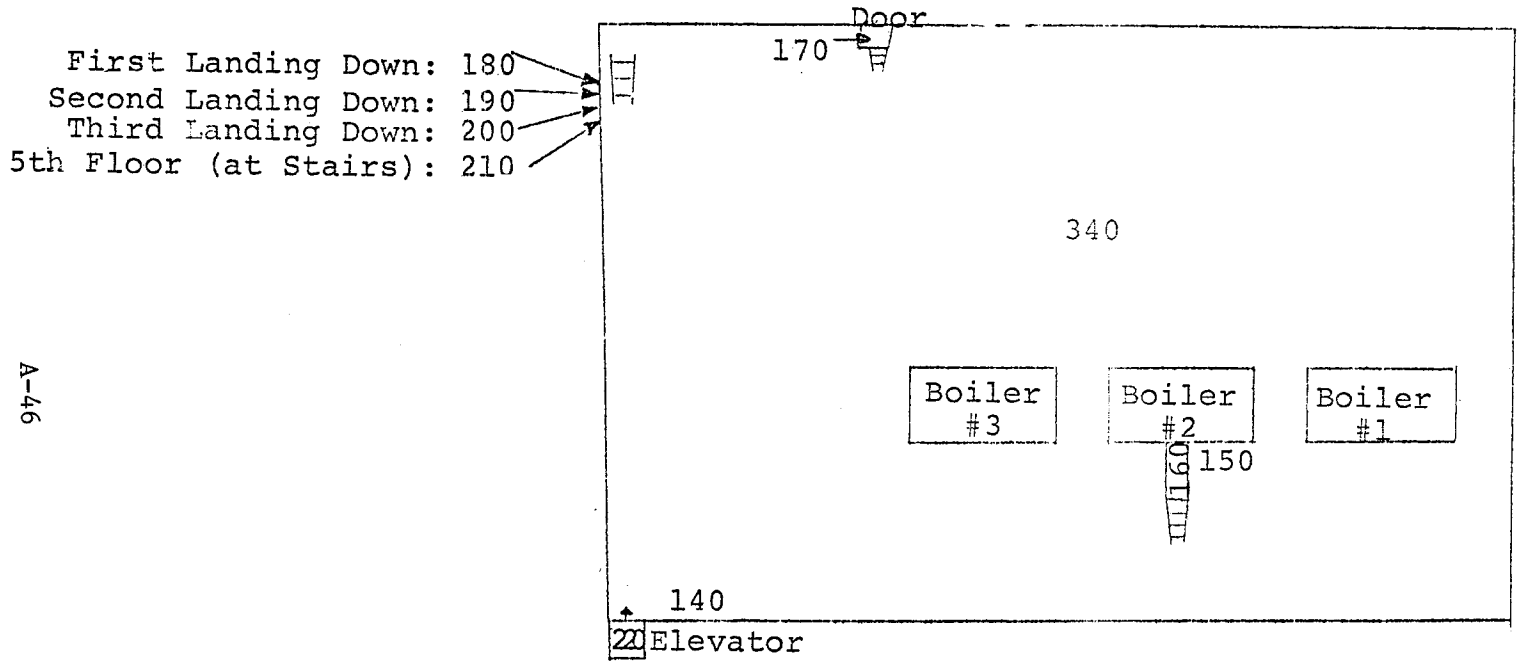


Figure 31

WORK AREA: POWER AND FUEL

Plant No.: 6

Building No.: 2

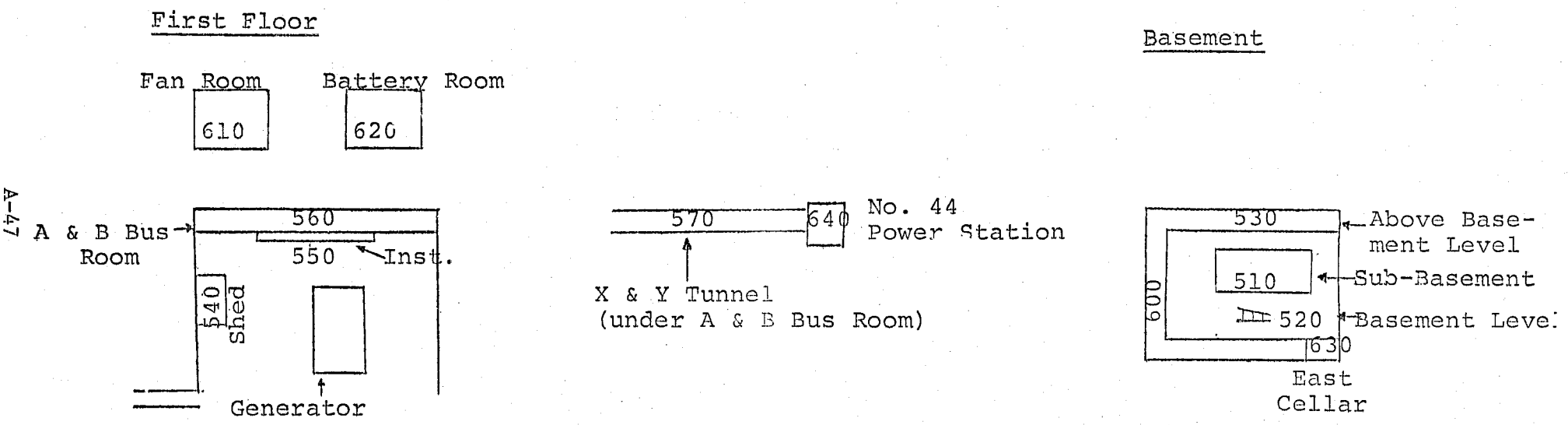
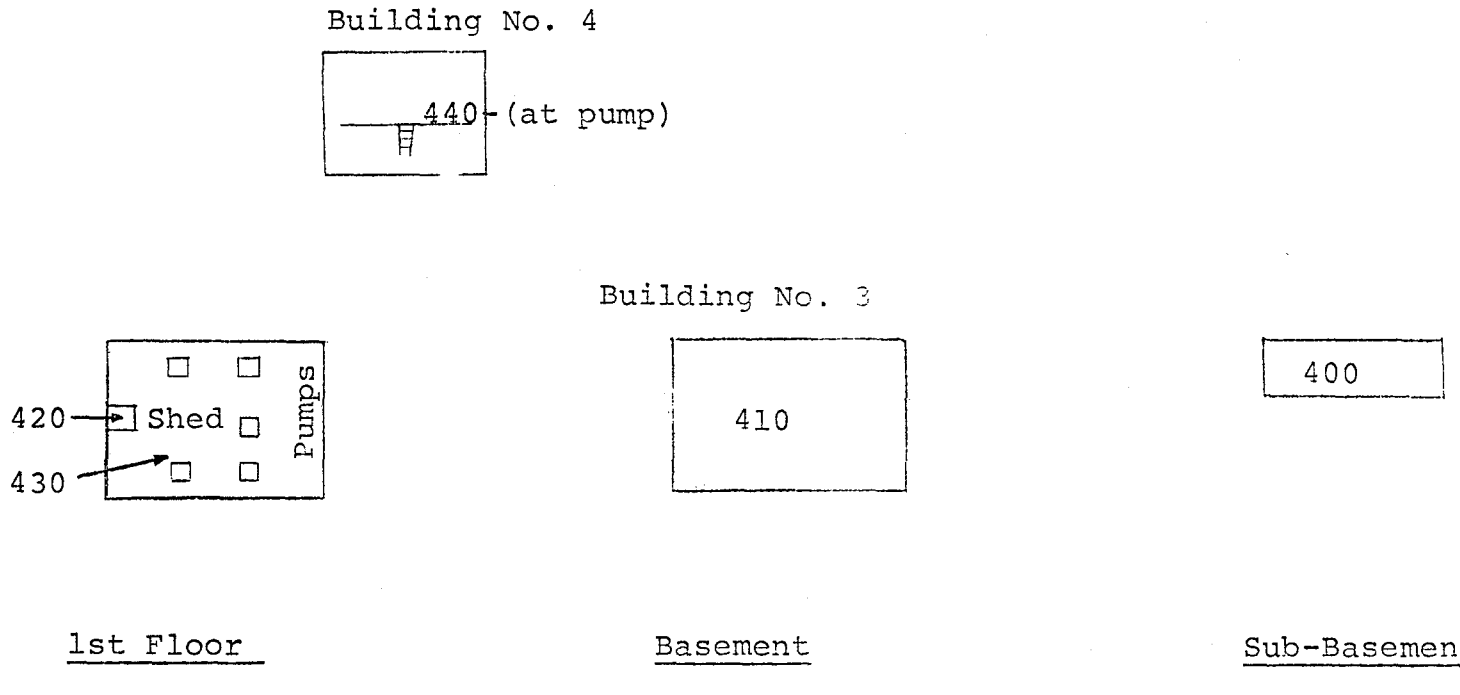


Figure 32

WORK AREA: POWER AND FUEL

Plant No.: 6

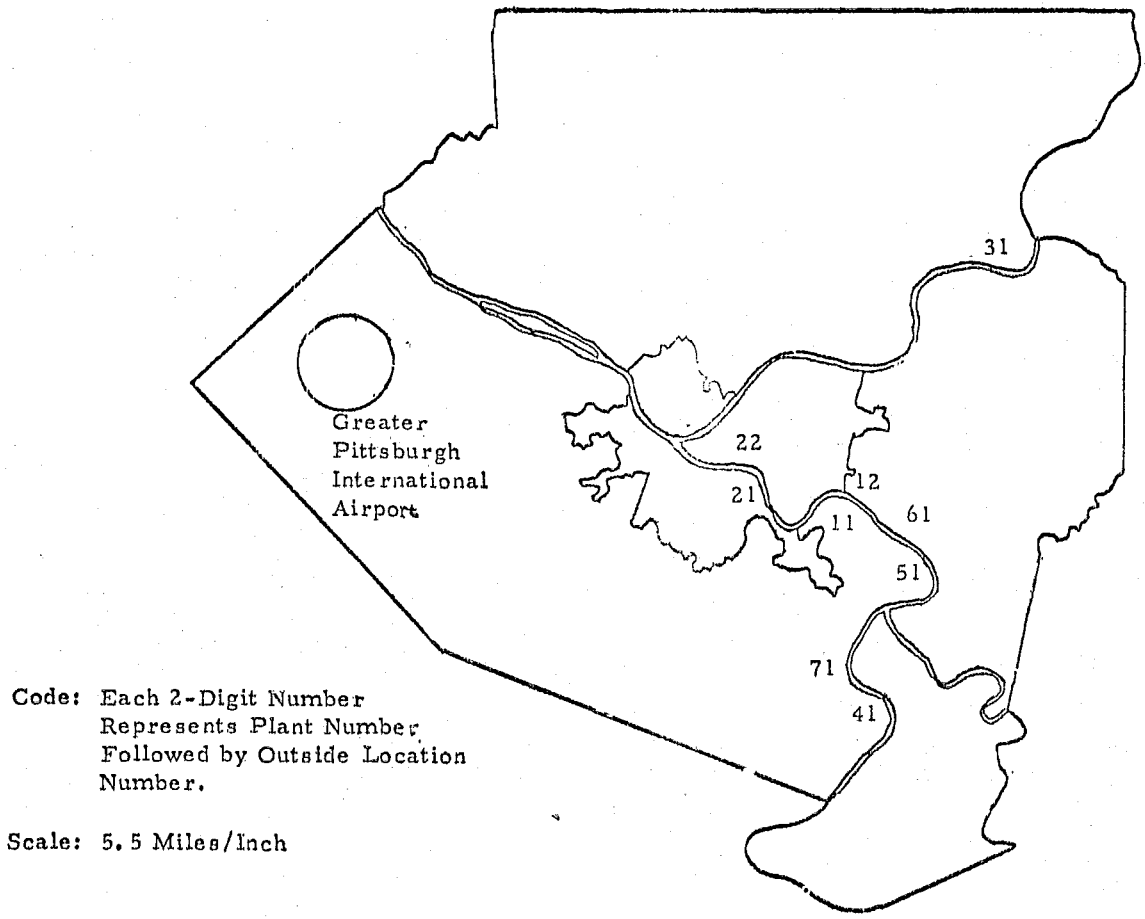
Building No.: 3,4



	Location Numbers
Group 1	0, 1, 2, 3, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 130, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 350, 440
Group 2	140, 150, 160, 170, 180, 190, 200, 210, 340
Group 3	400, 410, 420, 430, 510, 520, 530, 540, 550, 560, 570, 600, 610

Figure 33

Map of Allegheny County, Showing Locations of Outside Readings



Correspondence Between Codes on Figure 33 and Work Areas

Plant No.	Outdoor Location No.	Code	Work Area
1	1	11	Billet, Bloom, and Slab Mills Open Hearth Plate Mills
1	2	12	Blast Furnace Power and Fuel
2	1	21	Billet, Bloom, and Slab Mills Open Hearth
2	2	22	Blast Furnace Coke Plant Hot Strip Rolling
3	1	31	All
4	1	41	All
5	1	51	All
6	1	61	All
7	1	71	All

APPENDIX B

Instruments Used for Indoor Environmental Readings and Data Collection Forms

Figure 1

RSS-211 Heat Stress Monitor

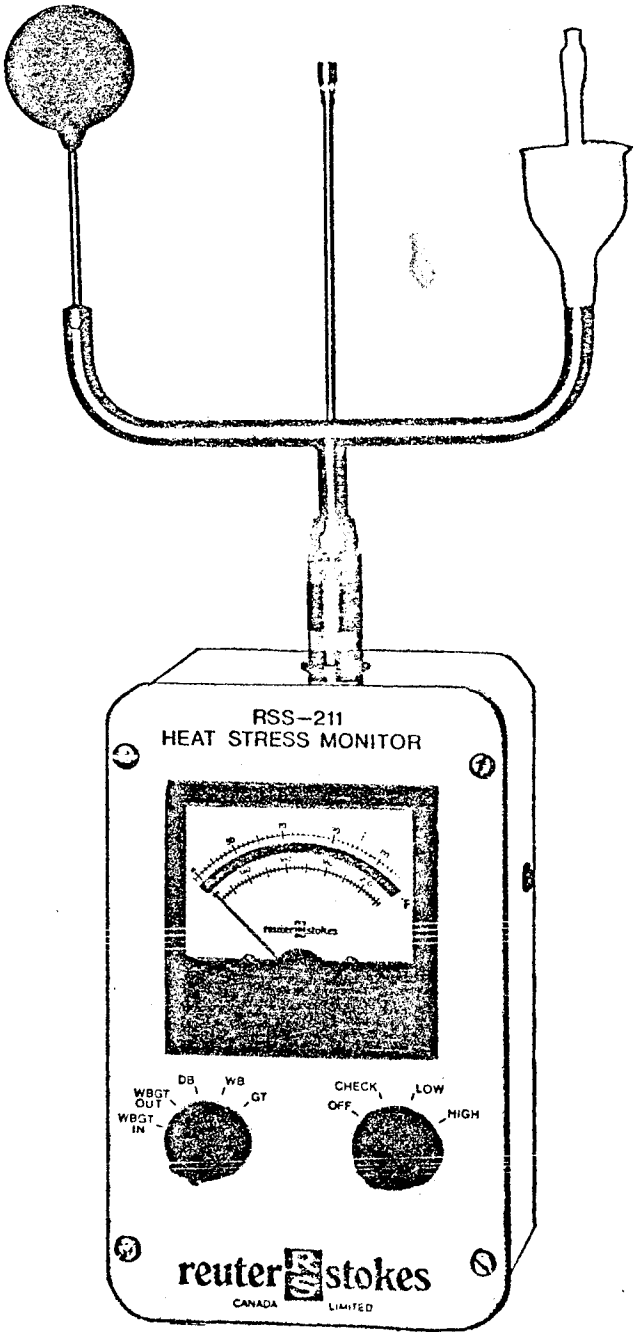
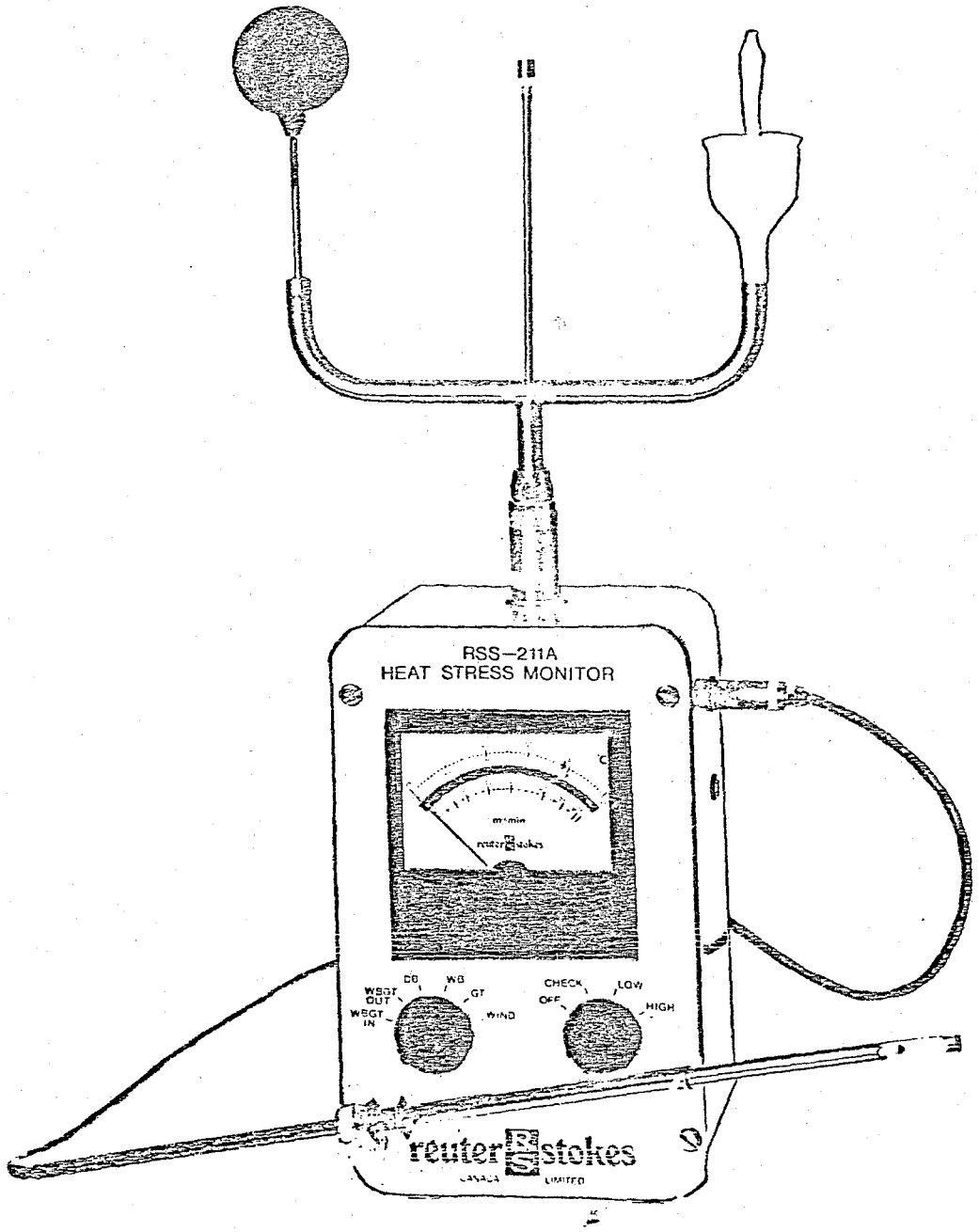


Figure 2

RSS-211A Heat Stress Monitor with Thermoanemometer



Form to Record Environmental Data

ENVIRONMENTAL DATA

PLANT NO._____ AREA NO._____ DATE_____ PAGE_____

(Map of work area)

TIME	ZONE	DB	NWB	PWB	GT	WIND SPEED	COMMENTS

Form to Record Activity Data

ACTIVITY INFORMATION

JOB NO._____ PLANT NO._____ AREA NO._____ DATE_____ PAGE_____

STARTING TIME_____

WORK NUMBERS

Sitting
- 10. At rest
- 11. Light arm work
- 12. Moderate arm work
- 13. Heavy arm work

Standing
- 20. At rest
- 21. Lifting
- 22. Digging
- 23. Shoveling
- 24. Light arm work
- 25. Moderate arm work
- 26. Heavy arm work
- 27. Light arm work and trunk work
- 28. Moderate arm work and trunk work
- 29. Heavy arm work and trunk work

Walking
- 30. Slowly
- 31. Rapidly
- 32. Moving empty wheelbarrow
- 33. Moving full wheelbarrow
- 34. Carrying with one hand
- 35. Carrying with two hands
- 36. Light arm work
- 37. Moderate arm work
- 38. Heavy arm work

Climbing
- 40. Up
- 41. Down

(Map of work area).

NO.	WORK	ZONE	MINUTES	SUPPLEMENTARY INFORMATION
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

APPENDIX C

Computation of Estimate of Relative Risk and Summary Chi-Square

Relative risks and summary chi-square test statistics were computed by work area and plant for 32 causes of death, adjusting for race, age at entry to the study, and calendar period of observation. Table C-1 displays the organization of the data for computation of these statistics. (Columns 1-4 display given data, while columns 5-8 require computation.)

As an example, mortality from a particular cause of death for white males in work area X, plant Y, could be adjusted for age and calendar period of observation by substituting the known data into the table and computing the statistics from the row for all ages, all years. Similarly, a table could be arranged for nonwhite males in the same work area and plant as above. Following summation of the last rows of the two tables, a relative risk and chi-square, adjusted for age at entry to the study, calendar period of observation, and race, may be computed by applying the formula to the combined sums.

By summation in a similar manner over appropriate tables, extension of the methodology above to other interest groups is straightforward.

Table C-1

Computation of Relative Risk and Summary Chi-Square[15, 16] Over Age Groups and Calendar Period of Observation

Age Group	Calendar Period	Standard Population		Interest Population			Relative Risk		
		No. at Risk (1)	No. Observed Deaths (2)	No. at Risk (3)	No. Observed Deaths (4)	No. Expected Deaths (5)	Variance (6)	Numerator (7)	Denominator (8)
<35	1953-57	a_{11}	b_{11}	c_{11}	d_{11}	e_{11}	f_{11}	g_{11}	h_{11}
	1958-62	.	.	.	.	.	.	.	.
	1963-67	.	.	.	.	.	.	.	.
	1968-70	a_{14}	b_{14}	c_{14}	d_{14}	e_{14}	f_{14}	g_{14}	h_{14}
35-44	1953-57	a_{21}	b_{21}	c_{21}	d_{21}	e_{21}	f_{21}	g_{21}	h_{21}
	1958-62	.	.	.	.	.	.	.	.
	1963-67	.	.	.	.	.	.	.	.
	1968-70	a_{24}	b_{24}	c_{24}	d_{24}	e_{24}	f_{24}	g_{24}	h_{24}
45-54	1953-57	a_{31}	b_{31}	c_{31}	d_{31}	e_{31}	f_{31}	g_{31}	h_{31}
	1958-62	.	.	.	.	.	.	.	.
	1963-67	.	.	.	.	.	.	.	.
	1968-70	a_{34}	b_{34}	c_{34}	d_{34}	e_{34}	f_{34}	g_{34}	h_{34}
55-64	1953-57	a_{41}	b_{41}	c_{41}	d_{41}	e_{41}	f_{41}	g_{41}	h_{41}
	1958-62	.	.	.	.	.	.	.	.
	1963-67	.	.	.	.	.	.	.	.
	1968-70	a_{44}	b_{44}	c_{44}	d_{44}	e_{44}	f_{44}	g_{44}	h_{44}
≥65	1953-57	a_{51}	b_{51}	c_{51}	d_{51}	e_{51}	f_{51}	g_{51}	h_{51}
	1958-62	.	.	.	.	.	.	.	.
	1963-67	.	.	.	.	.	.	.	.
	1968-70	a_{54}	b_{54}	c_{54}	d_{54}	e_{54q}	f_{54}	g_{54}	h_{54}
All Ages	All Periods	$A=\sum_{i=1}^{5}\sum_{j=1}^{4} a_{ij}$	$B=\sum_{i=1}^{5}\sum_{j=1}^{4} b_{ij}$	$C=\sum_{i=1}^{5}\sum_{j=1}^{4} c_{ij}$	$D=\sum_{i=1}^{5}\sum_{j=1}^{4} d_{ij}$	$E=\sum_{i=1}^{5}\sum_{j=1}^{4} e_{ij}$	$F=\sum_{i=1}^{5}\sum_{j=1}^{4} f_{ij}$	$G=\sum_{i=1}^{5}\sum_{j=1}^{4} g_{ij}$	$H=\sum_{i=1}^{5}\sum_{j=1}^{4} h_{ij}$

Table C-1 (Continued)

Where for the i^{th} age group and the j^{th} calendar period of observation:

a_{ij} = number of workers employed in jobs in the standard (comparison) population

b_{ij} = number of deaths of workers employed in jobs in the standard population

c_{ij} = number of workers employed in jobs of interest

d_{ij} = number of deaths of workers employed in jobs of interest

e_{ij} = expeded number of deaths of workers employed in jobs of interest

$$= \left(\frac{b_{ij}}{a_{ij}}\right)(c_{ij})$$

f_{ij} = variance of number of observed deaths in interest population

$$= \frac{(e_{ij})(a_{ij} - b_{ij} - c_{ij} + e_{ij})}{a_{ij} - 1}$$

$$g_{ij} = \frac{(d_{ij})(a_{ij} - b_{ij} - c_{ij} + d_{ij})}{a_{ij}}$$

$$h_{ij} = \frac{(b_{ij} - d_{ij})(c_{ij} - d_{ij})}{a_{ij}}$$

Table C-1 (Continued)

For all ages and all calendar periods:

$$\underline{\text{Relative Risk}} = \frac{G}{H}$$

$$\underline{\text{Summary Chi-Square}} = \frac{[\,|D-E| - \frac{1}{2}\,]^2}{F} \qquad (1 \text{ d.f.})$$

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