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OCCUPATIONAL EXPOSURE
TO
COKE OVEN EMISSIONS

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PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health of workers exposed to an ever-increasing number of potential hazards at their workplace. To provide relevant data from which valid criteria and effective standards can be deduced, the National Institute for Occupational Safety and Health has projected a formal system of research, with priorities determined on the basis of specified indices.

It is intended to present successive reports as research and epidemiologic studies are completed and sampling and analytic methods are developed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker.

This "work practices" document applies to occupational exposure to the emissions produced during the coking of coal. Due to the absence of reliable dose response data, this report does not recommend an environmental air standard as a safe exposure level. Instead, it recommends a combination of respiratory protection and "work practices" or operating procedures. These measures are intended to reduce not only the coke oven emissions, but also workers' exposure to the emissions.

I am pleased to acknowledge the contributions to this report on coke oven emissions by members of my staff, by Robert B. O'Connor, M.D., NIOSH consultant in occupational medicine, and by Edwin J. Kloos and Robert H. Schutz, consultants on respiratory protection. Valuable and constructive comments were presented by the Review Consultants on Coke Oven Emissions and by the ad-hoc committees of the American

Academy of Occupational Medicine and of the American Academy of Industrial Hygiene. The NIOSH recommendations for standards are not necessarily a consensus of all the consultants and professional societies that reviewed this criteria document on coke oven emissions. Lists of the NIOSH Review Committee members and of the Review Consultants appear on pages iv and v.

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The Office of Research and Standards Development, National Institute for Occupational Safety and Health, had primary responsibility for development of the criteria and recommended standard for Coke Oven Emissions. The draft document was developed by Mr. John V. Crable, Dr. Bobby F. Craft, Mr. Alan K. Gudeman, Dr. J. William Lloyd, Dr. Lester D. Scheel, Dr. William D. Parnes, and Dr. Joseph K. Wagoner; and the American Iron and Steel Institute, which developed some of the information under contract HSM-99-72-137. Bryan D. Hardin served as criteria manager and had NIOSH program responsibility.

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CRITERIA DOCUMENT: RECOMMENDATIONS FOR AN OCCUPATIONAL EXPOSURE STANDARD FOR COKE OVEN EMISSIONS

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I. RECOMMENDATIONS FOR COKE OVEN OPERATING PROCEDURES

The National Institute for Occupational Safety and Health recommends that worker exposure to coke oven emissions be controlled by requiring compliance with the following five sections.

Reduction of worker exposure can best be achieved by the elimination of emissions through improved engineering controls and coking methods. Operating procedures and respiratory protective devices are recommended pending development of sufficient data for identification of a safe environmental level of coke oven emissions. Pertinent new information will be reviewed periodically, and these recommendations will be revised where substantial changes in the control of emissions are achieved. These recommendations are not intended to supplant the existing standard for occupational exposure to coal tar pitch volatiles as set forth in part 1910.93 of the Federal Register, Volume 37, dated October 18, 1972, which can serve both as an index of worker exposure to coke oven emissions and as a measure of the effectiveness of engineering controls and operating procedures.

Section 1 - Operating Procedures

Engineering controls should be used to prevent workers' exposure to coke oven emissions. All new construction shall incorporate the best available engineering controls which will contribute to the elimination of coke oven emissions or which will reduce workers' exposure. The operator of each coke plant shall actively seek, design, and implement engineering controls, and shall maintain all engineering, ventilation, and physical control systems in efficient working order at all times.

Engineering controls for several jobs are listed below. If not already in use, these or alternate but at least equally effective engineering controls shall be implemented for the operations listed. Additional engineering controls for the protection of workers in these or other job descriptions shall be implemented as developed.

Pusher Operator

(a) A cab operating under positive air pressure with a filtered air supply.

(b) A smoke boot or comparable device installed on the leveler bar.

Quench Car Operator

A cab operating under positive air pressure with a filtered air supply.

Larryman - Lidman

(a) For lidmen, enclosed and readily accessible standby pulpit(s) under positive air pressure with a filtered air supply.

(b) A larry car cab operating under positive air pressure with a filtered air supply.

(c) Mechanical lid lifters.

(d) Individual drop sleeves, operated either from battery top or operator's cab.

(e) Mechanized gooseneck cleaners.

(f) Remote controlled dampering off and charging systems.

Door Machine Operator

A cab operating under positive air pressure with a filtered air supply.

Door Cleaners

Automatic door and jamb cleaners on pusher machines and door machines.

Workers' exposure to coke oven emissions can be reduced if certain basic procedures, generally common to the management of coke ovens, are incorporated into the operating procedures which are developed for individual coke batteries. The following basic provisions shall be incorporated into such operating procedures and additional controls developed and implemented as appropriate for each coke plant.

Prior to charging coal

(a) Gooseneck and standpipes shall be inspected, and any tar or carbon buildup removed to ensure free flow of gas.

(b) Liquor sprays on goosenecks shall be cleaned to ensure adequate flushing liquor flow at all times.

(c) Aspiration systems shall be inspected and any excessive accumulation of tar and carbon removed before any coal is charged into the oven.

(d) Standpipe caps shall be closed and properly sealed.

(e) The charging holes shall be inspected, and any carbon buildup which will effectively impede the flow of coal into the oven shall be removed.

(f) The larry car hoppers shall be filled with coal to a predetermined level as established for each individual hopper so that the oven is properly filled.

(g) The larry car shall be properly spotted over the oven to be charged to reduce emissions by allowing fast, efficient delivery of coal to the oven, and by preventing spilling.

Charging of Coal

(a) The coal shall be charged into the oven in accordance with specific procedures established to ensure that the charging operation is accomplished with the least evolution of emissions to the atmosphere.

(b) Procedures shall be established so that the leveling operation is carried out in a manner to minimize the evolution of smoke to the atmosphere.

(c) Charging hole lids shall be replaced as soon as possible after the coal has emptied from the hoppers. Charging hole lids that do not seat properly shall be sealed or replaced to prevent leakage.

(d) The aspiration system shall not be turned off until all the charging hole lids have been replaced.

(e) The top of the battery shall be maintained in a neat, orderly condition, free of coal.

(f) Procedures shall be established to adjust, repair, or replace self-sealing coke oven doors which fail to seal after the oven is charged. Luted doors which fail to seal after the oven is charged shall be reluted promptly.

Coking of the Coal Charge

(a) The coal charge shall be uniformly heated for a sufficient period to ensure proper coking. For each battery, procedures shall be established for measuring, adjusting, and maintaining of heating flue temperatures to achieve this objective.

(b) Procedures shall be established for checking the oven back pressure controls to maintain uniform pressure conditions in the collecting main.

Pushing of Coke

(a) For each battery, procedures shall be established for dampering off the ovens at the end of the coking cycle and removal of the charging lids to minimize emissions.

(b) Procedures shall be established so that doors and jambs are cleaned before the doors are replaced after the coke is pushed.

Section 2 - Medical

Medical surveillance shall be made available to all workers regularly assigned to work in any location on a coke oven or on a pusher machine or quench car. All such workers shall be offered a preplacement and annual medical examination which shall include a complete physical examination. The preplacement examination shall include a comprehensive medical history and occupational exposure history, and the annual medical examinations shall include interval medical and occupational exposure histories.

The following items shall be offered to the worker on all preplacement and annual medical examinations.

(a) A 14" x 17" posterior-anterior chest X-ray.

(b) A sputum cytology examination.

(c) A skin examination for premalignant and malignant lesions and evidence of hyperpigmentation or photosensitivity.

(d) A routine urinalysis to include tests for red blood cells.

(e) A medical questionnaire that includes the presence and degree of respiratory symptoms (breathlessness, cough, sputum production, and wheezing).

Respiratory function evaluation is also recommended as a guide to respirator usage and to determine whether the individual can wear a respirator.

Based on the judgment of the responsible physician, the frequency of the sputum cytology examinations may be increased or decreased depending upon the individual circumstances such as age, length of employment, smoking status, etc. Any worker with Papanicolaou grade 3, 4, or 5 should be referred immediately to an appropriate specialist for thorough medical evaluation. The return of such a worker to his former work will be based on the judgment of the responsible physician.

Dermatological examinations are primarily concerned with the prevention of skin cancer, and suspicious lesions should be treated expeditiously. The return of the employee to his former work will be based on the judgment of the responsible physician. Such workers should receive detailed instruction on the signs and symptoms of skin cancer, the necessity for good personal hygiene, and the possible risks associated with further exposure.

Workers should have an evaluation of pulmonary function before assignment to jobs requiring regular or periodic respirator usage, and annually thereafter, with spirometry including determination of $FEV_{1.0}$ and FVC performed initially and annually thereafter for all personnel permanently assigned to such jobs. An evaluation of workers temporarily assigned to such jobs is not needed if a respiratory evaluation made within the preceding 12 months indicated adequate pulmonary function. When there is evidence of impaired pulmonary function (or of cardiovascular disease) the employee's ability to wear a respirator and the advisability of permitting him to do so should be evaluated in view of the individual circumstances. A worker who shows pulmonary impairment, but is allowed to perform work requiring respirator usage, should be followed carefully and re-evaluated as medically indicated. Such a worker should be counseled on his increased risk and advised to report promptly any difficulties experienced.

The medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, and of the employer shall have access to all medical records. Physicians designated and authorized by any employee or former employee shall have access to his medical records.

Medical records shall be maintained for persons employed one or more years on the coke ovens. X-rays for the five years preceding termination of employment and all medical records with pertinent supporting documents shall be maintained at least 20 years after the individual's employment is terminated.

Section 3 - Labeling (Posting)

In order to warn employees of the health risks associated with exposure to coke oven emissions, the following warning signs/placards shall be affixed and maintained in readily visible locations at or near entrances or accessways to coke ovens and coke oven work stations.

WARNING

COKE OVEN EMISSIONS

HEALTH HAZARD

Prolonged exposure to coke oven emissions

may cause cancer

The following warning signs/placards shall be affixed and maintained in readily visible locations to identify the boundaries of those areas in which respiratory protection is required.

RESPIRATORY PROTECTION

REQUIRED BEYOND THIS POINT

These warning signs /placards shall be printed both in English, and in the predominant primary language of non-English-speaking workers, if any.

Section 4 - Respiratory Protection

Respirators as described herein shall be provided, used, and maintained as a means of respiratory protection for everyone in the locations specified. Respirators are not required for those persons in operating cabs equipped with air filtration systems which are at least as effective against particulate coke oven emissions as are the respirators specified for workers in that location on the oven. Personnel topside on the coke ovens shall wear a supplied air respirator or a powered air-purifying positive-pressure respirator with a half mask, full facepiece, hood, or helmet. Personnel on the side between the pinion walls, in or on door machines and pusher machines when between the pinion walls, and in or on quench cars shall wear any respirator approved for use topside on the coke oven or a nonpowered air-purifying respirator with a half mask or full facepiece. Other respirator types may be used if shown to be at least as effective as the respirator for which substituted. All air-purifying respirators shall use a replaceable dust filter or other particulate removing filter which has been tested and found effective against particulate coke oven emissions.

Respirators as described above shall be used pursuant to the following requirements:

(a) A medical evaluation of employees shall be performed to ensure that they have adequate ventilatory capacity to wear the prescribed respirators. (see Section 2)

(b) A respiratory protective program meeting the general requirements outlined in section 3.5 of American National Standard for Respiratory Protection Z88.2-1969 shall be established and enforced by the employer.

(c) The employer shall provide respirators in accordance with this section.

Respiratory protective devices shall be those approved either under the following regulations, or under 30 CFR 11 published March 25, 1972. The termination date of currently approved respirators described in 30 CFR 11 shall apply.

(a) Replaceable filter-type air-purifying respirator
30 CFR 14 (Bureau of Mines Schedule 21 B)

(b) Powered air-purifying positive-pressure respirator
30 CFR 14 (Bureau of Mines Schedule 21 B)

(c) Type C positive-pressure supplied air respirator
30 CFR 12 (Bureau of Mines Schedule 19 B)

Section 5 - Informing Employees of Hazard

When the control or elimination of potential safety and health problems is approached through the application of "operating procedures," much of the responsibility for the effectiveness of the program rests with the worker. The success of such an approach is highly dependent upon the worker's understanding of the work, its attendant hazards, and his motivation to follow procedures designed to minimize the risk of accident or illness. It is the responsibility of the employer to ensure the worker's understanding and motivation through effective training and education programs and other means at the employer's disposal. To help meet these needs, the following programs shall be initiated.

(a) Each individual working at the coke ovens shall be informed of the health hazards for coke oven workers and given the training necessary to ensure their understanding of the importance of operating procedures designed to reduce or eliminate exposure to coke oven emissions. At those times the carcinogenic hazards of coke oven emissions shall be presented to the worker, and the early symptoms and signs of cancer shall be explained, emphasizing lung, skin, and kidney cancer. Health professionals shall participate in the preparation and/or presentation of such training, which shall be coordinated with and may be presented in conjunction with other health and safety programs. Sessions shall be initiated for present employees within six months of the promulgation of a standard incorporating these recommendations. Thereafter, sessions shall be attended at least annually. New employees shall attend the first session offered after their employment.

(b) Within 30 days of the promulgation of a standard incorporating these recommendations, all present employees shall be given specific instruction by the supervisor for that job regarding the operating procedures for each job task. Thereafter, all new employees and employees new to a job shall receive this instruction before assuming their new duties. All workers who must wear respirators shall receive instruction on the proper use of the respirator and how to fit the respirator to the face.

II. INTRODUCTION

This report presents operating procedures prepared to meet the need for preventing occupational diseases arising from exposure to coke oven emissions. The document fulfills the responsibility of the Secretary of Health, Education, and Welfare, under the Occupational Safety and Health Act of 1970, to develop and establish recommended "occupational safety and health standards" which are described in Section 3(8) of that Act as standards which require "...the adoption or use of one or more practices, means, methods, operations, or processes, reasonably necessary or appropriate to provide safe or healthful employment and places of employment."

The National Institute for Occupational Safety and Health, after a review of data and consultation with others, formalized a system for the development of criteria upon which standards can be established to protect the health of workers from exposure to hazardous chemical and physical agents. It should be pointed out that these recommended operating procedures should result in the development of better engineering controls, and should not be used as a final goal, but are procedures to be followed until the necessary data are available to define the causative agent(s) and a safe exposure level.

These recommendations are designed as an aid to reducing workers' exposure to coke oven emissions through the application of operating procedures and engineering controls that are both feasible and attainable with existing technology. Until adequate dose response and environmental data are developed, the workers should be protected to the maximum extent practicable against exposure to these emissions through the use of respiratory protective devices and operating procedures. While it is recognized that the mandatory use of respirators is not the most desirable solution to the health hazards faced by coke oven workers, respiratory protection is recommended as a measure pending the development and implementation of new or improved coking methods and/or emission controls. These recommendations are not intended to supplant the existing standard for occupational exposure to coal tar pitch volatiles as set forth in part 1910.93 of the Federal Register, Volume 37, dated October 18, 1972, which can serve both as an index of worker exposure to coke oven emissions and as a measure of the effectiveness of engineering controls and operating procedures.

III. BIOLOGIC EFFECTS OF EXPOSURE

Extent of Exposure

The primary function of the coke plant is the production of metallurgical coke for use at the blast furnace. A secondary function is the recovery of chemical byproducts during the transformation (high temperature carbonization) of bituminous coal into coke. Prior to World War I, the main source of metallurgical coke in the United States was the beehive coke oven. These ovens were used solely for the production of coke, and the volatile matter produced during carbonization was emitted into the atmosphere. The byproduct coke plant, which allows for recovery of tar, oils, and chemicals from the volatiles, was introduced around the turn of the century, and by 1931 byproduct ovens accounted for 80% of coke production. Except for brief periods during World War II and the Korean War, this figure has been about 95%, with production by beehive ovens steadily declining. [1]

In addition to the production of metallurgical coke, there are several other methods of coal carbonization which, although they are not used in the United States at present, are of interest because of similar exposure to the volatiles and their byproducts, and there are previous reports [2-8] of unusual cancer experience in workmen employed in these areas. Major among these processes are the production of household gas in vertical and horizontal retorts, and the generation of producer gas for industrial use.

The modern byproduct coke plant is a semicontinuous operation which may be subdivided into three rather distinct work areas in terms of function and potential exposure to environmental hazards. These are: (a) the coal handling area where coal is received by rail or barge, and where provision is made for the handling, storage, and blending of several types of coal before transfer to the coke ovens; (b) the coke ovens, grouped into one or more batteries, with equipment for charging and discharging the ovens and the quenching of coke; and (c) a byproduct plant for recovery of gas and chemical products. [9]

In 1970, according to the Bureau of Mines, there were 64 slot-oven plants in the United States operating 13,218 coke ovens. [10] In a study [11] of steelworkers employed in Allegheny County, Pennsylvania, 1,327 men were enumerated as coke oven workers in two plants composed of 1,754 ovens. Applying the "coke oven worker-to-coke oven" ratio from this study to the number of coke ovens reported by the Bureau of Mines for 1970 would put the direct coke oven worker population at approximately 10,000 persons.

Historical Reports

It has long been recognized that some agent (or agents) produced during the combustion or distillation of bituminous coal is carcinogenic for the skin of man, and since the turn of the century a variety of industrial populations exposed to coal tar products have shown a special liability to cancer of the skin. [12] More recent studies [3-8,13-16] of men employed in some of these areas indicate that exposure to coal tar products and coke oven emissions also may result in increased liability for cancer of other organ systems.

The history of the "coal tar" cancers begins with the observations of scrotal cancer in London chimney sweeps by Percivall Pott [17] in 1775. Since that time, a large body of evidence has accumulated demonstrating that persons engaged in the carbonization of bituminous coal and those handling certain byproducts are at excess risk of scrotal and other forms of skin cancer. In a comprehensive study of the relationship between these tumors and exposure to coal tar products, Henry [12] reported an average annual scrotal cancer mortality rate of 21.1 per million in coke oven workers during the period 1911-1938 compared to a general population rate of 4.2. He also noted 84 cases of epitheliomatous ulceration or cancer of the skin (40 scrotal) in British coke oven workers for the period 1920 to 1943, and 11 fatal scrotal cancers among men with prior coke oven employment.

Epidemiological Studies

The first report of unusual lung cancer experience in men engaged in coal carbonization concerned Japanese producer gas workers. [2] Recent observations on this population show that gas producer men continued to show a lung cancer mortality rate 33 times that observed for other Japanese steelworkers many years after the facility was closed. [8] The excess lung cancer risk for gas producer men was confirmed by British studies of death certificates in England and Wales for the years 1921-1932. [18] Furthermore, this study showed that other coal carbonization and byproduct workers experienced greater than expected lung cancer mortality. The excess indicated for "gas stokers and coke oven chargers" in an extended report through 1938 was approximately three-fold. [13] More recent estimates for this group indicate an excess of only 32%, [14] and a report on a population-based study of British coke oven workers, although consistent with an excess of lung cancer mortality, was not particularly striking (14 deaths observed compared to 10 expected among retirees). [15] Possible explanations for variations in the estimates of excess risk for lung cancer among coke oven workers have been discussed elsewhere. [11] Doll, [4] in a 1952 study of gas works pensioners (gas retort workers), observed an 81% excess of lung cancer deaths in comparison with the general population. In 1971, Lloyd [11] reported that men employed as coke oven workers in Allegheny County, Pennsylvania had a lung cancer mortality rate two and one-half times that predicted by the experience of all steelworkers (31 deaths observed vs. 12.3 expected). A more recent study [16] of men employed during 1951-1955 at coke plants located throughout the U.S. and Canada confirms these findings, reporting relative risks for lung cancer almost identical to those observed in the original report.

An excess risk of bladder cancer among men employed at coal carbonization processes was first reported by Henry et al [19] in 1931. In their review of bladder cancer deaths for the period 1921-1928, they reported a greater than expected mortality for nine occupational groups exposed to coal gas, tar, and pitch. Furthermore, of the fifteen occupational groups exhibiting an excess of 50% or more, five were among the "coal tar" occupations. Forty-five bladder cancer deaths were observed in "gas stokers and coke oven chargers" compared to 33.7 expected. Unfortunately, this group cannot be subdivided to obtain an estimate for the coke oven chargers (larrymen). More recent studies of British gas retort workers confirmed an excess of bladder cancer for this group and suggested that these tumors may be associated with exposure to beta-naphthylamine at the gas retorts. [6,7] The observed incidence of bladder cancer in 4661 American coke oven workers was not excessive [16]; but the possibility of excess mortality cannot be ruled out when it is recognized that this is a comparatively rare cancer site with a long latent period, and that the study population has an extremely high risk for cancer of several other sites. On the other hand, Redmond et al [16] report that U.S. coke oven workers are experiencing an excess of cancer of the kidney (8 observed vs. 2.6 expected). This observation is consistent with the 1951 report of the British Registrar General which shows an excess risk of bladder and kidney tumors for men employed as "laborers and unskilled workers in coke ovens and gas works." [14]

Excess mortality from cancer of other sites for coke oven workers and other coal carbonization workers has been reported from several sources. [3,5,11,14,18,20] However, these findings are generally based on very limited data and have yet to be confirmed. At the same time, it should be pointed out that such responses could be part of the picture of a general carcinogenic response among coal carbonization workers who have already been noted to have extremely high risks of cancer from three sites (skin, [12] lungs, [2,4,8,11,13-16,18] and urinary organs [6,7,11,16]). Other cancers and cancer sites reported to be in excess from these limited studies are the larynx, [18] nasal sinuses, [3,5] pancreas [14] (which has been associated with exposure to beta-naphthylamine), [20] blood forming organs (leukemia), [14] and stomach. [14] Lloyd [11] has pointed out that American coke plant workers employed at work areas other than the coke ovens may be at increased risk of cancer of the digestive tract.

With the exception of the studies of lung and kidney cancer in American coke oven workers, data are not available to characterize the carcinogenic response in terms of extent of exposure. However, the accumulated evidence suggests the possibility of some difference in response according to carbonization process. As shown in Table VII-1, [9,21-25] there appears to be a positive relationship between temperatures attained during carbonization and the lung cancer response for men employed in the several areas. Doll et al reported that the bladder cancer response varies according to type of gas retort. [6] It has been noted, also, that the skin cancer response among persons exposed to coal tar products appears to be related to the level of distillation, with the rate increasing with successive distillations. [12] However, variation in response may be related to the materials and methods employed and nonoccupational factors such as personal habits and level of medicinal surveillance. For example, general population rates for skin cancer have been much higher in England and Wales than in the United States. [26,27]

As regards cancer of the lung, Lloyd [11] and Redmond et al [16] have shown that the response is related to both length of exposure and relative level of exposure as determined by specific job assignments at the coke ovens. In Allegheny County, men employed at the coke ovens for five or more years exhibited a mortality rate for lung cancer 3.5 times the expected rate, while the rate for all coke oven workers was 2.5 times that expected. The same relationship between length of exposure and lung cancer mortality was noted for coke oven workers outside of Allegheny County. An even greater difference for lung cancer is seen when the coke oven workers are classified into broad exposure groups according to work assignments. The lung cancer mortality rate for men employed at the top of the coke ovens is seven times the expected rate, whereas the rate for men employed exclusively at the sides of the ovens is 25% greater than expected. Among men employed at the coke ovens for five or more years, there is a definite gradient in response by work area with side oven workers showing a 46% excess, men with mixed side and topside employment but less than five years topside experiencing a rate almost three times the expected rate, and men employed full-time at the top of the ovens showing a lung cancer mortality rate 10 times that noted for all steelworkers. The distribution among 4661 coke oven workers of the eight kidney cancers reported by Redmond et al [16] does not suggest any association with a specific work area or length of exposure, but the overall relative risk for kidney cancer was 7.5. It should be noted that kidney cancers occurred predominantly in the parenchyma rather than in the kidney pelvis, the ureters, or bladder where the urine is more concentrated.

The possibility that the unusual lung cancer experience of coke oven workers might be accounted for by factors other than occupational exposure has been examined in detail by Lloyd [11] and Redmond et al. [16] Account has been taken of selective factors such as age, race, place of birth, residence, and employability, and it has been demonstrated that the differences observed cannot be explained by these factors. Consideration has also been given to the possibility that the excess lung cancer mortality of coke oven workers might be explained by differences in smoking habits, since it is known that tobacco use (primarily cigarette smoking) is positively correlated with the incidence of lung cancer. [28] In the single study of coal-carbonization workers for which smoking histories were available, Doll et al [6] ruled out cigarette smoking as a selective factor by showing that the smoking habits of persons employed in the several areas of the gas industry were comparable to those in the general population. Unfortunately, information on cigarette smoking history is not available for the American coke oven workers so that a direct approach to the question is not presently available. However, comparison of the age-specific lung cancer mortality of coke oven workers with mortality observed for American cigarette smokers during the same time period provides an indirect measure of the possible extent of effects due to cigarette smoking. The lung cancer mortality rates chosen for comparison come from a study of 293,000 U.S. veterans reported by Kahn. [28] These rates, according to smoking class and age, are contrasted with the lung cancer mortality rates for steelworkers and coke oven workers in Table VII-2. A detailed description of how these rates were determined is given elsewhere. [29]

Although different age groupings were used in the two studies, it can be seen in Table VII-2 that the steelworkers rate for men under age 45 is between the rate for total cigarette smokers ages 35-44 and 45-54. The same pattern is seen for each of the succeeding age groups. It appears that steelworker mortality may have been considerably higher than that for nonsmokers, somewhat higher than that for light smokers, but considerably lower than the mortality of heavy smokers. The lung cancer mortality rates for nontopside workers, although much higher than those observed for steelworkers, also are well within the limits defined for heavy smokers. On the other hand, the rates observed for topside coke oven workers are far greater than the rates for the veterans. For topside workers under age 45, for example, the rate of 141 is higher than that seen for heavy smokers of an older age (a rate of 95 for ages 45-54). The differential for the other age groups is even more striking. The topside worker rates of 819 for ages 45-54 and 1,356 for ages 55 and over are considerably higher than the veterans rates for any smoking class and age group. It is thus shown that the carcinogenic agent responsible for the excess lung cancer seen in topside workers has an effect considerably beyond that predicted by heavy cigarette smoking. While these findings do not rule out the possibility of some difference in coke oven worker mortality associated with differential smoking patterns, it indicates that the marked differences in lung cancer mortality between topside workers and other steelworkers cannot be explained solely by this factor.

There is some evidence that exposure to emissions at coke ovens and gas retorts may be associated with an increased occurrence of bronchitis. Doll et al [6] compared the death rate from bronchitis among men who had heavy exposure to products of coal carbonization at gas retorts to the rates in the general population and among all gasworkers. In both cases, the mortality in the heavily exposed group was significantly higher. A differential in bronchitis response according to type of retort house also was observed, with the largest excess in vertical houses while a lower level of mortality occurred at the horizontal retorts. Thus, the pattern of mortality from bronchitis was the reverse of that for lung cancer previously noted in this study. The authors tentatively concluded that exposure to products of coal carbonization at the retorts was causally related to increased mortality from bronchitis. However, other evidence suggests that differences in demographic characteristics [30] and in cigarette smoking habits [31] may account for at least some of the excess.

The same relationship between extent of exposure and incidence of malignant and nonmalignant respiratory disease also is suggested by the most recent findings on American coke oven workers, [16] but, the differences for nonmalignant respiratory disease are not significant and too few deaths have been observed to date to reach firm conclusions by specific respiratory disease.

In summary, evidence from other countries, involving a variety of processes, makes it clear that workers intimately exposed to the products from the carbonization of coal experience increased mortality due to cancer of the skin, [12] lung, [2,4,8,13-15,18] bladder, [6,7,14,19] and kidney. [14] There also is evidence from limited studies suggesting increased mortality due to nonmalignant respiratory disease [6,30]; and to cancer of the larynx, [18] pancreas, [14] stomach, [14] blood forming organs (leukemia), [14] and the nasal sinuses. [3,5] While not all of these diseases have been demonstrated in American coke oven workers, neither have they been eliminated as possible health problems. Among American coke oven workers, cancer of the lung, [11,16] and kidney, [16] and, among nonoven coke plant workers, cancer of the digestive system [11] have been shown to occur at an excessive rate. Since there is evidence that the disease response is related both to relative level and length of exposure, [11,16] reduction of the emissions or exposure to them should result in a reduced health hazard.

Animal Toxicity

Although coke oven emissions have not been directly tested experimentally for toxic or carcinogenic properties, many components have been studied separately. The carcinogenic properties of coal tar have been well known since the first chemically induced tumors in experimental animals were reported in 1918 by Yamagiwa and Ichikawa, who obtained papillomas and carcinomas after painting the ears of rabbits with coal tar. [32]

Benzo(a)pyrene, a chemical carcinogen frequently used for the experimental induction of cancer, was identified as a carcinogen following its isolation by investigators seeking to identify coal tar's carcinogenic constituents. [33] Another commonly used experimental chemical carcinogen found in coal tar is beta-naphthylamine, which has been demonstrated to be a potent bladder carcinogen in a variety of species, including the dog, [34] and the monkey. [35]

A variety of skin carcinogens have been identified in coal tar. Combes [36] divides coal tar's primary cutaneous carcinogens into two groups based upon molecular structure. Benz(a)anthracene and its derivatives, benzo(a)pyrene; 9,10-dimethyl-1,2-benzanthracene; 1,2,5,6-dibenzanthracene; 20-methylcholanthrene; 5,9,10-trimethyl-1,2-benzanthracene; and phenanthrene comprise the most important of the two groups. According to Combes' classification, the other group contains the "azo" compounds in which are included 4-amino-2,3-azo-toluene; 2,3-azotoluene; and p-dimethylamino azobenzene.

Co-carcinogenic factors can markedly affect the potency of a carcinogen. Bingham and Falk [37] reported that in skin painting studies utilizing C3H/He mice, the potency of both benzo(a)pyrene and benzo(a)anthracene was increased 1000-fold when the diluent used was n-dodecane, which has been identified as a product in the low temperature carbonization of coal. [38] Coal tar itself apparently has co-carcinogenic or promoting activity. Friedewald and Rous [39,40] found that coal tar, benzo(a)pyrene, and methylcholanthrene all produced growths of essentially the same types in rabbits. However, the promoting effect of the tar was much greater, leading to the rapid production of fleshy, vigorous, and rapidly enlarging tumors.

Using weanling rats, mice, rabbits, and hamsters in a 90-day continuous dosage inhalation study at coal tar concentrations of 0.2, 2.0, 10.0, and 20.0 mg/cu m, MacEwen [41] reported that 0.1 to 1.5 mg of tar accumulated in the lungs of the animals exposed to the 20 mg/cu m level. When these animal tissues were examined microscopically for morphologic or cytologic change, immediately following cessation of exposure, no tissue lesions attributable to the tar deposited in the tissue could be identified. Although it was too early to detect a carcinogenic response, a significantly reduced rate of body weight gain was observed in all animal groups except the rabbits, which lost weight.

Inhalation studies of longer duration have demonstrated the induction of lung cancer by coal tar. In inhalation studies using C3H mice, Horton et al [42] showed that after 35 weeks of daily exposures to atomized tar at 100 mg/cu m of air, squamous-cell tumors had developed in five of 33 test animals. In the same study, irritation of the lungs by the prior inhalation of formaldehyde was not found to predispose the mice to subsequent development of squamous cell carcinoma after inhalation of coal tar fumes.

Other inhalation studies have demonstrated a promoting effect apparently due to irritation of the lungs. For example, Kotin and Wisely [43] reported that hydrocarbons (ozonized gasoline) failed to produce squamous metaplasia and epidermoid carcinoma in C57 Black mice when inhaled alone, but did so when inhaled with influenza virus. Tye and Stemmer [44] found that coal tars with phenols removed were less potent carcinogens than coal tars with phenols and attributed the cocarcinogenic potential of phenols to their irritant properties. Laskin et al, [45] reported that rats inhaling benzo(a)pyrene and sulfur dioxide in combination, but not when either was inhaled alone, developed bronchial mucosal changes and tumors of bronchogenic origin, which they considered to closely simulate lung cancer in man. Both benzo(a)pyrene and sulfur dioxide are present in coke oven emissions and may interact in humans as they apparently do in rats.

These studies [32-45] demonstrate the carcinogenicity of coal tar and some of its components for a variety of animal species. Especially convincing are studies such as that by Laskin et al, [45] which report a response similar to human lung cancer. In the face of these studies and the occupational experience previously discussed, there can be little doubt that coal tar and some of its constituents are human carcinogens. Thus, the presence of coal tar and volatiles from coal tar in coke oven emissions may account, at least in part, for the increased incidence of cancer observed in coke oven workers.

IV. ENVIRONMENTAL DATA and RESPIRATOR USE

The exact nature of the airborne particulates generated by the production of coke is very difficult to define and may vary with atmospheric conditions, the type and mix of coal used, and coking time. Particulates consist primarily of coal and coke dust plus condensed particles resulting from the distillation of the coal. According to the American Iron and Steel Institute (AISI), [46] during the charging without steam aspiration of an 18-ton oven emissions consisted of: particulate matter - 2.2 pounds/charge; water vapor - 15.4 pounds/charge; and tar vapor - 0.66 pounds/charge. Condensed coal tar vapor thus comprised 3.6% of total emissions or, eliminating water vapor from consideration since it would be evaporated from a filter used in air sampling, 23% of the total particulates discharged. In the same report, AISI states that polycyclic aromatic hydrocarbons constituted 2.1-3.1% of the total particulates and 3.2-5.8% of the benzene soluble fraction, which includes not only polycyclic aromatic hydrocarbons but also the soluble fraction of coal dust and other particulates, in samples collected from the front platform of a larry car.

Studies of the characteristics of particulate coke oven emissions have indicated a bimodal distribution of particle sizes, with peaks at 1-2 microns and greater than 10 microns aerodynamic equivalent diameters. [46] Coke oven emissions were described as a mixture of irregularly shaped coal and coke particles and spherical carbonaceous-organic material with tarry, sticky material intermixed. This mixture is further complicated by the agglomeration of the smaller aerosols onto the larger, and adsorption of vapors. It was further reported that the benzene soluble fraction of total particulates increases with decreasing particle size.

In an effort to determine levels of exposure in coking operations, AISI [46] surveyed member companies having coke plants and requested exposure data relative to workers on and around coke ovens. Exposure data reported to AISI were collected during the period 1968-1972 by the member companies using standard industrial hygiene sampling procedures and represent 8-hour time-weighted average exposures. Although the data represent a wide range of coke oven operations, including both new and old batteries, and different operating procedures, the relative exposures for the eight job categories reported are apparent.

Data are summarized in Table VII-3. The range of concentrations of the benzene soluble fraction of coke oven particulate emissions, reported in milligrams per cubic meter, represents the maximum and minimum averages of the plant averages submitted. The mean shown (column 3) is the overall average of the individual plant averages. Included in Table VII-3 are less extensive data from studies made by the Pennsylvania Department of Environmental Resources beginning in 1966. [47]

A respirator is used to protect the wearer from the inhalation of harmful atmospheres. The conditions to be protected against range from those which are mainly a nuisance, as odor or irritation, to those which are immediately dangerous to life. The hazard may be due to one or more toxic contaminants or to an atmosphere significantly deficient in oxygen. The contaminants may be in the gaseous or particulate state or in combination. Protection may be needed for only minutes, as in rescue operations, or for hours, as in routine use.

For adequate protection against the variety of conditions which may be encountered in different operations, many types of respirators have been developed. Each has a particular field of application and limitations from the viewpoint of protection, as well as advantages and disadvantages from the viewpoint of operational procedures and maintenance. Detailed information on the selection and use of respirators can be obtained from the Respiratory Protective Devices Manual published in 1963 by the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists. The American National Standard Practices for Respiratory Protection, ANSI Z88.2-1969, also classifies, describes, and gives the limitations of respirators.

Respirators generally fall into the following classifications:

(a) Atmosphere-supplying respirators

(1) self-contained

(2) hose-mask

(3) air-line

(4) combination self-contained and hose-mask or air-line

(b) Air-purifying respirators

(1) gas and vapor (gas mask and chemical cartridge)

(2) particulate (dust, fog, fume, mist, smoke, and sprays)

(3) combination gas, vapor, and particulate

(c) Combination atmosphere-supplying and air-purifying respirators.

Requirements for approval of many types of respirators have been established by the Secretary of the Interior and the Secretary of Health, Education, and Welfare, and are published as Title 30, Code of Federal Regulations, Part 11, (30 CFR 11). Copies of the most recent requirements may be obtained from the Publications Distribution Section, U.S. Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pennsylvania 15213, or from the NIOSH Testing and Certification Laboratory, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505.

An air-purifying respirator for protection against particulates is equipped with a mechanical filter designed to remove particulate matter from the inspired air by capture on the filter, which is usually a fibrous pad. These respirators consist of a soft resilient full, half, or quarter mask facepiece to which is attached one or two filters through which the inspired air is drawn. Check valves, present in most mechanical-filter respirators, prevent exhaled breath from passing through the filters and allow it to be forced out through an exhalation valve in the facepiece to the surrounding atmosphere. The facepiece is held securely to the wearer's face by a head harness or headband.

The useful life of the mechanical filters is limited by the buildup of resistance to inhalation as the contaminant is removed by the filter. The higher the concentration of contaminant in the air drawn into the filter, and the greater the wearer's activity when using a nonpowered respirator, the more rapidly the resistance to inhalation increases. Because of this, the filters must be changed more frequently. In high dust concentrations, the Type C positive-pressure supplied air respirator must be selected.

A powered air-purifying positive-pressure respirator contains a motor-blower which draws the contaminated air of the workplace through a mechanical filter, and discharges it into a facepiece, hood, or helmet. The device can be designed to ensure a positive pressure in the facepiece, so that high protection can be achieved. Since leakage through the facepiece seal is reduced and inhalation resistance is eliminated, lower facepiece seating forces can be used. Additionally, the air sweeping through the mask may provide some facial cooling while reducing moisture build-up in the mask. Therefore, acceptance of this device by the wearer should be higher than that of the conventional air-purifying respirator.

The air supply system for the powered air-purifying respirator may be designed to be worn by a worker or separately mounted with an air-line connection to the worker. For mobility, the power pack is mounted on the worker. This additional weight and bulk, however, may be unacceptable to the worker. As with the nonpowered air-purifying respirator, the filter service life will depend upon the concentration of air contaminant.

A battery-powered air-purifying respirator for coke oven workers has been developed and evaluated [48] under the direction of William A. Burgess and under the sponsorship of the American Iron and Steel Institute. This half mask respirator has been evaluated by AISI [46] as having an average protection factor of 30.

The Type C positive-pressure supplied air respirator is an air-line respirator consisting of a half mask or full facepiece to which respirable air is supplied through a small diameter hose. The air-line respirator is the most comfortable to wear. There is little or no resistance to inhalation, and the flow of air usually provides a cooling and refreshing effect. The wearer supports little weight other than the facepiece and connecting hose. A limitation is the necessity of trailing the small diameter hose connecting the facepiece to the air source, which limits the travel of the wearer.

The problem of providing adequately fitting respirators is complicated by the wide range of facial sizes and shapes which must be accommodated. Differences in facial sizes and shapes result from a wide variety of factors, the most significant of which include age, sex, and race.

Facial hair, such as beards or sideburns, make it impossible to achieve an airtight seal between the facepiece and the face, particularly with the half mask respirator. Even the stubble resulting from failure to shave daily can cause serious inward leakage of contaminated air. Therefore, workers who are to wear respirators with half or full facepieces should be cleanly shaven.

Providing respiratory protection for individuals wearing corrective glasses is a serious problem. The ability to wear corrective glasses with a half mask depends on the face fit. It is possible to obtain a seal with a poorly fitting respirator, but quite often the device will rest so high on the face as to make the wearing of glasses impossible. For a full face mask, a proper face seal cannot be established if the temple bars of the eyeglasses extend through the sealing edge. Some full facepiece designs provide for the mounting of special corrective lenses within the facepiece.

Any respirator affects the wearer's ability to see. The half mask and the attached elements can restrict normal downward vision appreciably. Diminished vision in the full face mask may be caused not only by the facepiece, but also by the design and placement of the eyepieces.

Speech transmission through a respirator can be difficult, annoying, and fatiguing to workers. Mere movement of the jaws in speaking may cause leakage between the facepiece and face, especially with the half mask respirator.

The wearer's comfort, and his acceptance of the distress caused by wearing a respirator, are no less important than the device's effectiveness. All factors such as improperly fitted respirators, uncomfortable resistance to breathing, and limitation of vision and speech transmission affect a respirator's acceptability.

V. BASIS FOR RECOMMENDED STANDARDS

Accumulated epidemiological evidence gathered in many countries and for various occupational groups conclusively demonstrates that workers intimately exposed to the products of the combustion or distillation of bituminous coal are at increased risk of cancer at many sites. These sites include cancer of the skin, [12] lung, [2,4,8,11,13-16,18] larynx, [18] nasal sinuses, [3,5] kidney, [14,16] bladder, [6,7,19] stomach, [11,14] intestine, [11] pancreas, [14] and blood forming organs (leukemia [14]).

While the increased cancer risk has been widely demonstrated, the exact causative agent or combination of agents in coke oven emissions has not been identified, nor has a dose-response relationship been established. The American Conference of Governmental Industrial Hygienists has recommended a Threshold Limit Value for coal tar pitch volatiles (benzene soluble fraction) of 0.2 mg/cu m as a level which, due to instability in the composition of the volatiles, should "minimize" exposure to the carcinogens present. [49] This same level has been adopted as the Federal standard for coal tar pitch volatiles and, as such, its applicability includes occupational exposure to coke oven emissions. However, in the absence of information on a safe level, this environmental standard can be considered only an index of worker exposure.

Although the threat to workers' health is not limited to benzene soluble compounds, the benzene soluble fraction of total particulates has been generally accepted as an index of the health hazard. Because the polycyclic aromatic hydrocarbons in coke oven emissions are associated with the particulates [46] and are benzene soluble, that fraction may have some validity as a general index of the health hazard. On the other hand, the report by Laskin et al [45] at least suggests that the health hazard may be associated not with polycyclic hydrocarbons alone, but with polycyclic hydrocarbons and irritant gases in combination. If that is the case, then the usefulness of the benzene soluble fraction of total particulates as an index of the health hazard may be somewhat questionable. Additionally, this suggests the possibility that respiratory protection against gases as well as particulates may be needed if coke oven emissions cannot be reduced or eliminated through process changes, engineering controls, and operating procedures. At present, it appears that adequate respiratory protection is provided by particulate-removing respirators, especially if total emissions are reduced or eliminated, but additional research is needed to specifically demonstrate whether respiratory protection against gases is needed or not.

The type of respiratory protection to be provided and the conditions for its use can be based on an estimation of the health hazard as indicated either by some environmental measurements or by the area of employment. As discussed in the preceding paragraph, the traditional environmental index, the benzene soluble fraction of total particulates, is suspect as an index of the health hazard. Furthermore, there is no good evidence with which to determine a safe level of exposure, so that an environmental level could only be chosen arbitrarily. On the other hand, the disease response has been correlated with the degree of exposure as determined by the area of employment. [16] Therefore, it is recommended that respiratory protection be based upon the area of employment, at least until information becomes available on which a meaningful environmental index and a safe exposure level can be established.

It is difficult to anticipate the performance of various filter media against particulate coke oven emissions. The AISI reported [46] that some filters, which allowed penetration of less than 10% when tested against 0.3 micron dioctylphthalate (DOP), performed poorly against coke oven emissions. Burgess [48] found that resin-impregnated deep wool batting allowed leakages up to 1.8% of total particulates (6.5% or less of the benzene soluble fraction). The next most efficient medium tested against coke oven emissions was a high-efficiency glass fiber-organic fiber filter, which allowed less than 0.02% penetration of DOP. Against coke oven emissions, the penetration was up to 6.3% of total particulates (up to 12.0% of the benzene soluble fraction). These reports illustrate the need for filter media to be tested specifically against coke oven emissions to verify their efficiency, which may not be the same as against another substance.

The AISI report [46] indicates that the quarter mask facepiece may be more acceptable to the workers than is the half mask since the former is more lightweight and cooler to wear due to its reduced seal area. However, the half mask is stabilized by the chin cup and the facial seal often can be maintained despite facial movements during talking or involuntary facial movements during work. [46] With effective fitting and a choice of masks, the half mask will also fit most workers. Thus, while a good seal can be achieved with the quarter mask, it is less secure than is the seal with a half mask. For this reason, the quarter mask is not recommended for use on the coke ovens, since a good facial seal is critical to effective respiratory protection. A full facepiece offers a still better facial seal, but may be unacceptable for use in at least some jobs if vision is too restricted.

If opposition to a given respirator or facepiece type is encountered, the worker can be offered an alternative respirator in keeping with the provisions of Section 4, but most acceptance problems probably can be overcome as the worker becomes more accustomed to the use of respirators. Burgess [48] surveyed wearer acceptance of his experimental respirator and reported that workers' reactions to protective devices were modified by a number of factors, among them previous experience with such devices, the workers' impression of the hazard, and the employee relations "climate" at the plant. In general, if a worker was willing to wear the test respirator for an extended period, initial adverse reactions were mollified.

Although a dose-response relationship has not been established, the existence of such a relationship is suggested by findings that the increased risk for lung cancer is related both to exposure time and to degree of exposure as indicated by area of employment, [16] so that, if exposures can be reduced, the incidence of disease should be reduced concurrently. Additionally, the type of cancer response appears to differ with the area of employment. While topside workers are reported to experience the higher lung cancer rate, nontopside coke oven workers are reported to have a higher rate for kidney cancer, [16] but nonoven coke plant workers apparently are at excess risk for cancer of the digestive system. [11]

Until information on which to establish a safe environmental level becomes available, the seriousness of the diseases associated with exposure to coke oven emissions makes prompt reduction of occupational exposures to the lowest practicable level important. Therefore, recommendations are made for more complete protection through a combination of operating procedures and respiratory protection. While it is felt that sufficient reliance cannot be placed on the environmental standard as measured by the benzene soluble fraction of total particulates (coal tar pitch volatiles), that standard should continue to be utilized to describe the environment and to assess the effectiveness of control methods, including process changes, because no better criterion is available.

Since safe exposure levels are unknown, equally important to the protection of the workers' health is regular medical evaluation, especially medical evaluation directed toward the early detection of those diseases for which coke oven workers have increased risk. This primarily involves cancer of three systems: the skin, respiratory and urinary systems. Early detection of cancers in these systems is a primary objective of the medical program outlined in Section 2. Because the greatest excess risk, up to ten times the expected rate, [11,16] is for lung cancer, two medical examinations (X-ray and sputum cytology) specifically directed toward its detection are recommended. The only screening tests of proved, albiet insufficient, value in the detection of lung cancer, [49,50] these tests can be complementary in that cases missed by one method may be detected by the other. [50-53] This can be attributed to the observation that X-rays seem to be more accurate in regard to peripheral bronchogenic cancers, and sputum cytology seems more likely to be positive for cancers of the larger central bronchi. [50,51] Cytology appears to be more effective in the detection of early malignancies, [54] while it is estimated that approximately 60% of lung cancer's natural history precedes the earliest radiographic detection. [50]

False-positive and false-negative reports can occur with both methods. As suggested by Davies, [50] the effectiveness of sputum cytology can be affected by the accumulated experience of those conducting the screening tests. In nine reports in which there were fewer than 100 established cases of lung cancer, false-positives averaged 5.25%. In four studies with more than 250 cases each, false-positives averaged 2.9%, while in one study with 368 cases, false-positives were less than 1%. Chronic infection and inflammatory conditions were given as the predominant causes of the false-positive results. [50] On the other hand, radiologic false-suspects in screening programs can be greater. For example, in one mass-screening chest X-ray program, the number of "lung tumor suspects" was over 14 times the number of cases eventually diagnosed. [55-57] Since it does not localize the lesion, positive sputum cytology with negative chest films presents a problem in medical management, but bronchoscopy, bronchial brushing, fiberoptic bronchoscopy, and differential cytology have been used successfully in localizing occult bronchogenic carcinomas. [51,58,59]

False-negative reports occur with both methods, as evidenced by the detection of lung cancer by one method but not the other, [53] and by follow-up studies which indicate lung cancer was present in an earlier screening but was missed then by both methods. [53] Several authors [51,53] point out that lung cancer or other anomalies can be visible, in retrospect, in X-rays but not noted by one or several reviewers in the initial screening. The success of sputum cytology is dependent upon obtaining a satisfactory specimen, which requires considerable skill on the part of the technician collecting samples. Consequently, false-negative cytology usually results from improperly collected specimens, lack of a good deep cough specimen, or obstruction in the bronchi, rather than misinterpretation since the skilled cytologist rarely misses malignant cells in the slide. [50] Both X-rays and sputum cytology, then, present difficulties of follow-up, false-negative results, and false-positive results; but, in view of their complementary nature, several authors recommend the use of both methods for screening high-risk populations. [50,52,53] Both methods are recommended here, because coke oven workers are a high risk group. Methods for the handling and preparation of cytological samples and criteria for staging cells are discussed elsewhere. [60-62]

The occurrence of skin cancer has not been demonstrated to cause excessive mortality among American coke oven workers. Nevertheless, it has been well documented in the past among other workers exposed to the products of bituminous coal combustion or distillation. [12] It has been suggested that good personal hygiene in combination with prompt treatment of suspicious lesions can prevent all deaths due to skin cancer. [3] Therefore, regular dermatological examinations should be included in all medical examinations for the prompt detection and treatment of cutaneous cancers.

Excess kidney cancer has been reported in American coke oven workers [16] as well as in British workers in coke ovens and gas works. [14] Although excess cancer of the bladder has not been demonstrated in American coke oven workers, it has been reported in British gasworkers. [6,7,19] Beta-naphthylamine, which has also been identified in coal tar, [38] is present in the British workers' environment and has been suggested as the cause of the excess bladder cancer. [6,7] Regular urinalyses, including tests for red blood cells, can be helpful in the detection of cancer in the urinary system. Although hematuria may indicate cancer of the urinary tract, it may also derive from other causes, but it is a serious sign which must be further investigated. [63]

Excessive mortality due to cancer of the digestive system has been reported both in British coke oven and gasworkers [14] and in American coke plant workers. [11] Since the disease has not been demonstrated to be a cause of increased mortality among American coke oven workers, no specific screening procedure for its detection has been recommended. Nevertheless, physicians should at least be aware of the possibility of an increased incidence of digestive system cancers, and should thoroughly investigate any symptoms which could be indicative of cancer in that system.

Although primarily for guidance in respirator use, annual respiratory function evaluations should reveal evidence of some respiratory diseases. Additionally, respiratory function evaluations can assist in the placement of persons suffering from impaired cardiopulmonary function.

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TABLE VII-1

TEMPERATURE RANGE OF CARBONIZING CHAMBERS
AND EXCESS OF LUNG CANCER REPORTED

Carbonizing Chamber	Temperature Range*	Percent Excess of Lung Cancer Reported
Vertical Retorts	400 - 500 C	27% [6]
Horizontal Retorts	900 - 1100 C	83% [6]
Coke Ovens	1200 - 1400 C	255% [11]
Japanese Gas Generators	1500 C	800% [11]

* References for Temperature: 9, 21-25

The figure shown for coke oven workers is for men with five or more years experience to provide contrast with the British gas workers who had worked at least five years at the retorts.

Table VII-2

Lung Cancer Mortality Rates for Selected US Smoking Groups[a], 1954-1962 and Steelworker Groups[b], 1953-1961

AGE							
U. S. Smokers	35-44		45-54		55-64		65-74
Steelworkers		<45		45-54		≥55	
Never smoked, or only occasionally	-		-		10		30
Total cigarette smokers	5		42		138		281
Cigarettes smoked: 1 to 9 per day	-		-		53		132
Cigarettes smoked: over 39 per day	-		95		316		606
Steelworkers		12		127		162	
Coke oven, never topside		9		230		313	
Coke oven, topside		141		819		1,356	

a. Rate for U. S. smokers - Annual probability of death x 10^5

b. Rate for Steelworkers - (Probability of death, 1953-1961) x $10^5/9$

TABLE VII-3

SUMMARY OF EXPOSURES OF COKE OVEN WORKERS TO COKE OVEN EMISSIONS (BENZENE SOLUBLE FRACTION OF TOTAL PARTICULATES)

A SUMMARY OF SEPARATE AIR SAMPLING STUDIES BY AISI MEMBER COMPANIES AND PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES.

Operator (source of info.)	No. of Samples	Range* (mg/cu m)	Average** (mg/cu m)
Larry car operator			
AISI	106	0.78-6.4	2.2
PA	39	0.28-8.8	3.1
Lidman			
AISI	140	1.0-5.6	2.6
PA	61	0.42-18.	3.2
Door Machine Operator			
AISI	85	0.31-5.1	1.2
PA	25	0.04-6.5	2.1
Door Cleaner/Luterman			
AISI	172	0.31-3.2	1.1
Patcher			
AISI	10	0.71-1.3	0.99
Heater			
AISI	60	0.12-2.4	0.57
PA	39	N.D.-3.0	1.1
Quench Car Operator			
AISI	70	0.05-1.2	0.44
PA	23	N.D.-7.0	0.94
Pusher Operator			
AISI	78	0.15-0.82	0.40
PA	23	N.D.-0.93	0.39

* AISI DATA is a range of the mean coke oven emission concentrations reported for each job description by each coke plant studied.

** AISI DATA is the average of mean concentrations for each coke plant studied.

N.D. = None Detected

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