V. WORK PRACTICES

Occupational health hazards associated with coal liquefaction can also be minimized or reduced by the use of work practices, defined here as all aspects of an industrial safety and health program not covered under engineering controls (discussed in Chapter IV). Work practices cover areas such as personal protective equipment and clothing, specific work procedures, emergency procedures, medical surveillance, and exposure monitoring.

Specific Work Procedures

Workplace safety programs have been developed in coal liquefaction pilot plants to address risks of fire, explosion, and exposure to toxic chemicals [1]. These programs are patterned after similar programs in petroleum refineries and the chemical industry. Most coal liquefaction pilot plants have written policies and procedures that govern work practices in the plant. These include procedures for lockout of electrical equipment, tag-out of valves, fire and rescue brigades, safe work permits, vessel entry permits, wearing safety glasses and hardhats, housekeeping, and other operational safety practices [1].

Personnel responsible for the development of occupational health and safety programs for coal liquefaction plants should refer to general industry standards (29 CFR 1910) to identify mandatory requirements. In addition, they should use voluntary guidelines of similar industries, recommendations of equipment manufacturers, and their own operating experience and professional judgment to match programs with specific plant operations. Reiteration here of all appropriate requirements would detract from recommendations for work practices needed in coal liquefaction, but unlikely to be applied in other industries. This section describes special work practices to minimize the risk of accidents or adverse chronic health effects to workers in coal liquefaction plants.

(a) Training

The effective use of good work practices and engineering controls depends on the knowledge and cooperation of employers and employees. Verbal instructions, supplemented by written and audiovisual materials, should be used to inform employees of the particular hazards of specific substances, methods for handling materials, procedures for cleaning up spills, personal protective equipment requirements, and procedures for emergencies. A continuing employee training program is also necessary to keep workers abreast of the latest procedures and requirements for worker safety and health in the plant. Additionally, experience at coal liquefaction pilot plants indicates that provisions are needed to evaluate employee comprehension of safety and health information [1].

(b) Operating Procedures

It is common practice in industry to develop detailed procedures for each phase of operation, including startup, normal operation, routine maintenance, normal shutdown, emergency shutdown, and shutdown for extended periods. In developing these procedures, consideration should be given to provisions for safely storing process materials, for preventing solidification of dissolved coal, for cleaning up spills, and for decontaminating equipment that requires maintenance. In high-pressure systems, leaks are major safety considerations during plant startup. Therefore, the entire system should be gradually pressurized to an appropriate intermediate pressure. At this point, the whole system should be checked for leaks, especially at valve outlets, blinds, and flange tie-ins. Particular attention should be given to areas that have been recently repaired, maintained, or replaced. If no significant leaks are found, the system should be slowly brought up to operating pressure and temperature. If leaks are found, appropriate maintenance should be performed [16].

Equipment such as the hydrotreater, which operates at high pressures, should be inspected routinely at predetermined intervals to determine maintenance needs. Because of the limited operations of pilot-plant and bench-scale coal liquefaction processes, the inspection or monitoring intervals and the equipment replacement intervals cannot be specified. These intervals should be based on actual operating experience. A similar approach should be used to develop monitoring and replacement intervals for equipment susceptible to erosion and corrosion, eg, slurry pumps and acid-gas removal units. Monitoring requirements, schedules, and replacement intervals should be part of the QA program for coal liquefaction plants.

(c) Confined Space Entry

In several plants, a permit system controls worker entry into confined spaces that might contain explosive or toxic gases or oxygen-deficient atmospheres [1,112,113]. Previously, NIOSH discussed the need for frequent air quality testing during vessel entry [16]. Procedures for vessel entry were also described, including recommendations for respiratory protection, and lifelines. Surveillance by a third person, equipped to take appropriate rescue action, has been recommended where hydrogen sulfide is present [65]. Safety rules developed at one coal liquefaction facility [1] recommended: (1) disconnecting the lines containing process materials rather than using double-block-and-bleed valves and (2) providing ventilation sufficient for air changeover six times per hour in the vessel during entry. This recommended procedure may not be feasible in all circumstances, but should be adopted where possible; disconnecting piping from vessels would provide greater protection to workers than would closing double-block-and-bleed connections.

(d) Restricted Areas

Access in coal liquefaction plants should be controlled to prevent entry of persons unfamiliar with the hazards, precautions, and emergency procedures of the plant. Access at one hydrocarbonization unit is controlled by using warning signs, red lights, and physical barriers such as doors in areas subject to potential PAH contamination [106]. Due to the small scale of this operation, the use of doors is feasible for access control. Different mechanisms, such as fences and gates, would serve similar functions in larger facilities. At other plants, access controls include visitor registration with the security guard, visitor escorts in process areas, and fences around the plant [1]. Because of the variety of potential hazards (including highly toxic chemicals, fire, and explosion), process areas should be separated from other parts of the plant by physical barriers. Access to the plant area should be controlled by registration of those requiring entry. Visitors should be informed of the potential hazards, the necessary precautionary measures, and the necessary actions to take in an emergency. An entry log should be kept of workers entering restricted areas. This will facilitate medical followup of high-risk groups in the event of occupational illness among workers. In addition, the visitors' log would help account for people at the plant if there were an accident or emergency.

(e) Decontamination of Spills

Spills and leaks from equipment containing toxic liquids should be cleaned up at the earliest safe opportunity. Cleanup operations should be performed and directly supervised by employees instructed and trained in safe decontamination and disposal procedures [16]. Correction may be as simple as tightening a pump-seal packing gland or switching to spare equipment, or as drastic as initiating a process shutdown. Small spills may be effectively contained by a sorbent material [16]. Used sorbent material should be disposed of properly.

Safety rules have been developed for the removal of solidified coal from equipment and plugged lines [1]. Whenever possible, hydroblasting should be used to remove the solidified coal extract rather than forcing the blockage out with high pressure. When high-pressure water is used, the pressure limits of the piping and equipment should not be exceeded. Access of plant personnel to the work area should be restricted while hydroblasting is in progress or while equipment is under pressure [1].

Dried tar is difficult to remove from any surface, particularly from the inside of process vessels. Manual scraping and chipping and the use of chlorinated hydrocarbon solvents or commercial cleansers are common methods of cleanup [16]. Where organic solvents are used for this purpose, special care is necessary to prevent employee exposure to solvent vapors. Cleaning solvents should be selected on the basis of low toxicity and low volatility, as well as for effectiveness. If necessary, approved respirators should be worn while using such solvents. Steam stripping is also commonly used and is effective, but it can cause significant inhalation exposures to airborne particulates (low-boiling-point residues may vaporize and high-boiling-point materials may become entrained in induced air currents). Generally, steam stripping is not recommended because it may generate airborne contaminants. There may be instances, however, where it must be used, eg, on small, confined surfaces. If it is used, emissions should be contained and treated.

The use of strippable paints or other effective coatings should be considered for plant surfaces where tar can spill. Suitable coatings are impenetrable by tar and do not adhere well to surfaces. Thus, any tar can be removed along with the coating, and the surface repainted [16].

Hand tools and portable equipment frequently become contaminated and present an exposure hazard to employees who use them. Contaminated tools and equipment can be steam-cleaned in an adequately ventilated facility [1] or cleaned by vapor degreasing and ultrasonic agitation [16].

(f) Personal Hygiene

Good personal hygiene practices are important in controlling exposure to coal-derived products. Instructions related to personal hygiene have been developed in facilities that use coal-derived products. Employees are advised to: (1) avoid touching their faces or reproductive organs without first washing their hands [1,114], (2) report to the medical department all suspicious lesions, eg, improperly healing sores, dead skin, and changes in warts or moles [114], (3) wash skin with soap and water after direct contact with coal-derived products [1,114], and (4) wash their hands, forearms, face, and neck after completion of each operation involving known or suspected carcinogens [1,114].

Showers are commonly required at the end of each shift in facilities where potential carcinogens are handled [1,113-115]. To segregate contaminated clothing from street clothing, employers should provide a shower facility with a double locker room. Figures XVIII-5 and XVIII-6 give examples of floor plans for shower and clothes change facilities [116].

If either exposed skin or outer clothing is significantly contaminated, the employee should wash the affected areas and change into clean work clothing at the earliest safe opportunity. Because of the importance of this protective measure, supervisory employees must be responsible for ensuring strict compliance with this requirement.

An adequate number of washrooms should be provided throughout each plant to encourage frequent use by workers. In particular, washrooms should be located near lunchrooms, so that employees can wash thoroughly before eating. It is very important that lunchrooms remain uncontaminated, minimizing the likelihood of workers inhaling or ingesting materials such as hydrocarbon vapors, particulates, or coal-derived oils. It is necessary that workers remove contaminated gloves, boots, and hardhats before entering lunchrooms. Therefore, some type of interim storage facility should be provided [16].

Cheng [115] reported that experience at one SRC pilot plant indicated that the following skin care products were useful for and accepted by workers: waterless hand and face cleaners, emollient cream, granulated or powdered soap for cleansing the hands, and bar soap for use in showers. NIOSH recommends providing bar soap in showers and lanolin-based or equivalent waterless hand cleaners in all plant washrooms and in the locker facility. The use of organic solvents such as benzene, carbon tetrachloride, and gasoline for removing contamination from skin should be discouraged for two reasons. First, solvents may facilitate skin penetration of contaminants and thus hinder their removal [16]. Second, many of these solvents are themselves hazardous and suspected carcinogens. Workers should thoroughly wash their hair during showers [1,16], and should pay particular attention to cleaning skin creases, fingernails, and hairlines. All use of sanitary facilities should be preceded by a thorough hand cleansing [16].

In summary, good personal hygiene practices are needed to ensure prompt removal of any potentially carcinogenic materials that may be absorbed by the skin. These practices include frequent washing of exposed skin surfaces, showering daily, and observing and reporting any lesions that develop. To encourage good personal hygiene practices, employers should provide adequate washing and showering facilities in readily accessible locations.

Personal Protective Equipment and Clothing

The proper use of protective equipment and clothing helps to reduce the adverse health effects of worker exposure to coal liquefaction materials that may be hazardous. Many types of equipment and clothing are available, and selection often depends on the type of exposure anticipated.

(a) Respiratory Protection

Respirators should be considered as a last means of reducing employee exposure to airborne toxicants. Their use is acceptable only (1) after engineering controls and work practices have proven insufficient, (2) before effective controls are implemented, (3) during the installation of new engineering controls, (4) during certain maintenance operations, and (5) during emergency shutdown, leaks, spills, and fires [16].

When engineering controls are not feasible, respiratory protective devices should reduce worker inhalation or ingestion of airborne contaminants and provide life support in oxygen-deficient atmospheres. Although respirators are useful for reducing employee exposure to hazardous materials, they have certain undesirable usage aspects. Some problems associated with respirator usage include (1) poor communication and hearing, (2) reduced field of vision, (3) increased fatigue and reduced worker efficiency, (4) strain on heart and lungs, (5) skin irritation or dermatitis caused by perspiration or facial contact with the respirator, and (6) discomfort [117,118]. Facial fit is crucial to effective use of most air-purifying respirators; if leaks occur, air contaminants will bypass a respirator's removal mechanisms. Facial hair, eg, beards or long sideburns, and facial movements can prevent good respirator fit [117,118]. For this reason, at least one coal liquefaction plant [1] prohibits beards, and mustaches extending below the lip.

Selection of appropriate respirators is an important issue in environments where a large number of chemicals may be present in mixtures. In general, factors to consider for respirator selection include the nature and severity of the hazard, contaminant type and concentration, period of exposure, distance from available respirable air, physical activity of the wearer, and characteristics and limitations of the available respiratory equipment [59].

Where permissible exposure limits (PEL's) for contaminants have been established by Federal standards, NIOSH and OSHA guidelines for respirator selection should be followed. In addition to exposure limits, the NIOSH guidelines examine skin absorption or irritation, warning properties of the substance, eye irritation, lower flammable limits, vapor pressures, and concentrations immediately dangerous to life or health [119]. Situations where PEL's cannot be used to determine respirator selection require individual evaluation. Such conditions are likely in coal liquefaction plants, especially during maintenance that requires line breaking or vessel entry, or during emergencies.

Training workers to properly use, handle, and maintain respirators helps to achieve maximum effectiveness in respirator protection. Minimum requirements for training of workers and supervisors have been established by OSHA in 29 CFR 1910.134. These requirements include handling the respirator, proper fitting, testing facepiece-to-face seal, and wearing it in uncontaminated workplaces during a long trial period. This training should enable employees to determine whether respirators are operating properly by checking them for cleanliness, leaks, proper fit, and exhausted cartridges or filters. The employer should impress upon workers that protection is necessary and should train and encourage them to wear and maintain respirators properly [119]. One way to do this is to explain the reasons for wearing a respirator. According to ANSI Standard Z88.2, Section 7.4 [120], the following points should be included in an acceptable respirator training program: (1) information on the nature of the hazard, and what may happen if the respirator is not used, (2) explanation of why more positive control is not immediately feasible, (3) discussion of why this is the proper type of respirator for the particular purpose, (4) discussion of the respirator's capabilities and limitations, (5) instruction and training in actual respirator use, especially with an emergency-use respirator, and close and frequent supervision to ensure proper use, (6) classroom and field training in recognizing and coping with emergency situations, and (7) other special training as needed. At least one major coal liquefaction research center has adopted these points for inclusion in its safety manual [121].

Respirator facepieces need to be cleaned regularly, both to remove any contamination and to help slow the aging of rubber parts. Employers should consult the manufacturers' recommendations on cleaning methods, taking care not to use solvent materials that may deteriorate rubber parts.

(b) Gloves

Gloves are usually worn at coal liquefaction plants in cold weather, when heavy equipment is handled, or in areas where hot process equipment is present. Where gloves will not cause a significant safety hazard, they should be worn to protect the hands from process materials. Gloves made of several types of materials have been used in coal liquefaction plants, including cotton mill gloves, vinyl-coated heavy rubber gloves, and neoprene rubber-lined cotton gloves [1,115]. After using many types of gloves, the safety staff at the PETC did not find any that satisfactorily withstood both heat and penetration by process solvents [1].

Sansone and Tewari [122,123] studied the permeability of glove materials. They tested natural rubber, neoprene, a mixture of natural rubber and neoprene, polyvinyl chloride, polyvinyl alcohol, and nitrile rubber against penetration by several suspected carcinogens. The glove materials were placed in a test apparatus, separating equal volumes of the permeant solution and another liquid miscible with the permeant. Samples were extracted periodically and analyzed by GC. For one substance tested, dibromochloropropane, the concentration that penetrated neoprene after 4 hours was approximately 10,000 times greater than the concentration that penetrated butyl rubber of the same thickness; polyvinyl alcohol, polyethylene, and nitrile rubber were less permeable than neoprene [122]. Measurable penetrant concentrations, ie, greater than 10^{-6} volume percent, were reported after 5 minutes for most glove materials tested against dibromochloropropane, acrylonitrile, and ethylene dibromide [122]. Readily measurable amounts of nitrosamines penetrated glove materials within 30 minutes [123]. Although the chemicals tested are not present in coal liquefaction processes, the test results suggest that the protection afforded by gloves can vary markedly with the chemical composition of the materials being handled.

In another study related to the selection of gloves, Coletta et al [124] investigated the performance of various materials used in protective clothing. They surveyed published test methods for relevance in evaluating protective clothing used against carcinogenic liquids, but no specific methods were found for testing permeation resistance, thermal resistance, or decontamination. More than 50 permeation tests were conducted in an apparatus similar to the one used by Sansone and Tewari, with the protective material serving as a barrier between the permeant and distilled water. Nine elastomers were evaluated for resistance to permeation by one or more of nine carcinogenic liquids. Of particular importance are the tests conducted with coal tar creosote and benzene, because benzene and some constituents of creosote, eg, phenols and benzo(a)pyrene, have been identified in coal liquefaction materials. Neoprene resisted penetration by creosote for 270 minutes, and benzene for 25 minutes [124]. Butyl rubber and Viton were more resistant to both creosote and benzene than was neoprene. Other elastomers were not tested for resistance to creosote, but were inferior against benzene. In general, a wide variation in permeability was observed for different combinations of barrier and penetrant. These data demonstrate the need to quantitatively evaluate the resistance of protective clothing materials against coal liquefaction products before making recommendations for suitable protective clothing.

NIOSH recently reported on an investigation at the Los Alamos National Laboratory and on a research project to develop a permeation testing protocol. It was demonstrated that some materials of garments made to protect workers may be ineffective when used for more than a short time. Design criteria are being developed for the degree of impermeability of protective material and for the specific materials to use against various chemicals.

No quantitative data on glove penetration by coal liquefaction materials have been reported. In the absence of such data, it is prudent to assume that gloves and other protective clothing do not provide complete protection against skin contact. Because penetration by toxic chemicals may occur in a relatively short time, gloves should be discarded following noticeable contamination.

(c) Work Clothing

Proper work clothing can effectively reduce exposure to health hazards from coal liquefaction processes, especially exposure to heavy oils. Work clothing should be supplied by the employer. The clothing program at one coal liquefaction pilot plant provides each process area worker with 15 sets of shirts, slacks, tee-shirts, underpants, and cotton socks; 3 jackets; and 1 rubber raincoat [115]. Thermal underwear for use in cold weather is also provided at this plant [1]. Work clothing should be changed at the end of every workshift, or as soon as possible when contaminated.

Cotton clothing with a fairly close weave retards the penetration of many contaminants, yet permits the escape of body heat. Nylon coveralls used at one coal liquefaction plant proved to be easier to clean than cotton coveralls (ME Goldman, written communication, February 1978). However, most synthetic fibers melt when exposed to flame. For comparison, Nylon 6,6 sticks at 445°F (229°C) and melts at about 500°F (260°C), while cotton deteriorates at 475°F (246°C) [125].

There is evidence that clothing worn under the coveralls aids in reducing skin contamination. In a 1957 experiment at a coal hydrogenation pilot plant [37], "pajamas" (buttoned at the neck with close-fitting arm and leg cuffs) worn under typical work clothes prevented contaminants absorbed by the outer clothing from coming into contact with the skin. They also provided an additional barrier to vapors and aerosols. However, in some instances, particularly in hot climates, this practice may contribute to heat stress, which is a potentially more significant hazard [16].

All work clothing and footwear should be left at the plant at the end of each workshift, and the employer should be responsible for proper cleaning of the clothing. Because of the volume of laundry involved, in-plant laundry facilities would be convenient. Any commercial laundering establishment that cleans work clothing should receive oral and written warning of potential hazards that might result from handling contaminated clothing. Operators of coal liquefaction plants should require written acknowledgment from laundering establishments that proper work procedures will be adopted.

In one study [37], experiments showed that drycleaning followed by a soap and water laundering removed all but a very slight stain from work clothing. One industry representative suggested that using the above procedures required periodic replacement of the drycleaning solvent to prevent buildup of PAH's (ME Goldman, written communication, February 1978).

Outer clothing for use during cold or inclement weather should be selected carefully to ensure that it provides adequate protection and that it can be laundered or drycleaned to eliminate process-material contamination [16].

(d) Barrier Creams

Barrier creams have been used in an attempt to reduce skin contact with tar and tar oil and to facilitate their removal should contamination occur [1]. Using patches of pig skin, the PETC tested several commercially available barrier creams for effectiveness in preventing penetration of fluorescent material [1]. The barrier cream found to be most effective is no longer manufactured. Weil and Condra [7] showed that barrier creams applied before exposure to pasting oil and various methods of washing after the oil had reached the skin only slightly delayed tumor induction in mice. Simple soap and water wash appeared to be as efficient as any treatment [7]. This study indicated that barrier creams were insufficient protection against skin contamination by coal liquefaction products and that they should not be used in place of other means of protection.

(e) Hearing Protection

Exposure to noise levels in excess of the NIOSH-recommended standard of 85 dBA for an 8-hour exposure may occur in some areas of a coal liquefaction plant. Engineering controls should be used to limit the noise to acceptable levels. However, this is not always possible, and it may be necessary to provide workers with protective hearing devices.

There are two basic types of ear protectors available: earmuffs that fit over the ear, and earplugs that are inserted into the ear. Workers should choose the type of ear protector they want to wear. Some may find earplugs uncomfortable, and others may not be able to wear earmuffs with their glasses, hardhats, or respirators.

A hearing conservation program should be established. As part of this program, workers should be instructed in the care and use of ear protectors. This program should also evaluate the need for protection against noise in various areas of the coal liquefaction plant and should provide workers with a choice of ear protectors suitable for those areas. Workers should be cautioned not to use earplugs contaminated with coal liquefaction materials.

(f) Other Protective Equipment and Clothing

Specialized protective equipment and clothing, including safety shoes, hardhats, safety glasses, and faceshields, may be required where the potential for other hazards exists. One company requires rubber gloves with long cuffs, plastic goggles, and a rubber apron for the handling of coal tar liquid wastes, and a thermal leather apron, thermal leather gloves, full-face visor shield, and thermal leather sleeves for the handling of hot solids samples [126]. Requirements for other types of protective clothing and equipment should be determined in specific instances based on the potential exposure.

Steel-toed workshoes should provide adequate protection under most circumstances. However, workers involved in the cleanup of spills or in other operations involving possible contamination of footwear should be provided with impervious overshoes. Rubber-soled overshoes are not recommended, because the rubber may swell after contact with process oils [16].

Medical Surveillance and Exposure Monitoring

(a) Medical Surveillance

Medical monitoring is essential to protect workers in coal liquefaction plants from adverse health effects. To be effective, medical surveillance must be both well timed and thorough. Thoroughness is necessary because of the many chemicals to which a worker may be exposed (see Appendix VI). In addition, worker exposure is not predictable; it can occur whenever any closed process system accidentally leaks, vents, or ruptures. Not all adverse effects of exposure to the chemicals are known, but most major organs may be affected, including the liver [127], kidneys [128], lungs [129], heart [58], and skin [130].

A medical surveillance schedule includes preplacement, periodic, and post-employment examinations. The preplacement examination provides an opportunity to set a baseline for the employee's general health and for specific tests such as audiometry. During the examinations, the worker's physical job-performing capability can be assessed, including his ability to use respirators. Finally, the examination can detect any predisposing condition that may be aggravated by, or make the employee more vulnerable to, the effects of chemicals associated with coal liquefaction. If such a condition is found, the employer should be notified, and the employee should be fully counseled on the potential effects.

Periodic examinations allow monitoring of worker health to assess changes caused by exposure to coal chemicals. The examinations should be performed at least annually to detect biologic changes before adverse health effects occur. Physical examinations should also be offered to workers before termination of employment in order to provide complete information to the worker and the medical surveillance program.

A comprehensive medical examination includes medical histories, physical examinations, and special tests. History-taking should include both medical and occupational backgrounds. Work histories should focus on past exposures that may have already caused some effect, such as silicosis [129], or that may have sensitized the worker, as may be the case with many coal-derived chemicals [17]. Physical examinations should be thorough, and medical histories should focus on predisposing conditions and preexisting disorders. Some clinical tests may be useful as general screening measures.

A thorough medical history and physical examination will permit an examining physician to determine the presence of many pathologic processes. However, laboratory studies are necessary for early determination of dysfunction or disease in organs that are relatively inaccessible and that have a high degree of functional reserve. In the screening aspect of a medical program, worker acceptance of each recommended laboratory test must be weighed against the information that the test will yield. Consideration should be given to test sensitivity, the seriousness of the disorder, and the probability that the disorder could be associated with exposure to coal liquefaction materials. Furthermore, wherever possible, tests are chosen for simplicity of sample collection, processing, and analysis. In many instances, tests are recommended because they are easy to perform and are sensitive, although they are not necessarily specific. If the results are positive, another more specific test would be requested. The choice of tests should be governed by the particular chemical(s) to which a worker is exposed. Appropriate laboratory tests and elements of the physical examination to be stressed are described in the following paragraphs, according to target organ systems.

(1) Skin

NIOSH has studied some chemicals or mixtures that are similar to those found in coal liquefaction processes and that are known to affect the skin. For example, the NIOSH criteria document on coal tar products [17] cited cases of keratitis resulting from creosote exposure and cases of skin cancer produced from contact with crude naphtha, creosote, and residual pitch. In addition, there is the possibility of developing inflamed hair follicles or sebaceous glands. In the NIOSH criteria document on cresol [127], skin contact was shown to produce a burning sensation, erythema, localized anesthesia, and a brown discoloration of the skin. Other relevant NIOSH criteria documents that list skin effects as major concerns include those on carbon black [56], refined petroleum solvents [130], coke oven emissions [18], and phenols [61].

Skin sensitization may occur after skin contact with, or inhalation of, any of these chemicals. Patch testing can be used as a diagnostic aid after a worker has developed symptoms of skin sensitization. However, patch tests should not be used as a preplacement or screening technique, because they may cause sensitization in the employee. Skin sensitization potential is best determined by medical history and physical examination.

Written and photographic records of skin lesions are one method of monitoring potential development of skin carcinomas [1]. When comparison of these records indicates any changes in appearance of the skin lesions, the worker should be referred to a qualified dermatologist for expert opinion. A clinical diagnosis of cancer or a "precancerous" condition should be substantiated by histologic examination.

(2) Liver

The NIOSH criteria document on cresol [127] indicated that liver damage may result from occupational exposures to this chemical. Medical surveillance with emphasis on preexisting liver disorders has been recommended by NIOSH in criteria documents on coal gasification [16] and phenols [61].

Because of the vast reserve functional capacity of the liver, only acute hepatotoxicity or severe cumulative chronic damage will produce recognizable symptoms such as nausea, vomiting, diarrhea, weakness, general malaise, and jaundice. Numerous blood chemistry analyses are available to screen for early liver dysfunction. The tests most frequently employed in screening for liver disease are serum bilirubin, serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), gamma glutamyl transpeptidase (GGTP), and isocitric dehydrogenase.

(3) Kidney

Impaired renal function has been indicated by NIOSH criteria documents on cresol [127], carbon disulfide [128], coke oven emissions [18], and coal tar products [17]. Kidney function can be screened by urinalysis followed up with more specific tests.

(4) Respiratory

Inhalation of chemicals associated with coal liquefaction may be toxic to the respiratory system. For example, sulfur dioxide and ammonia are respiratory tract irritants [60,131]. Substantial exposures to ammonia can produce symptoms of chronic bronchitis, laryngitis, tracheitis, bronchopneumonia, and pulmonary edema [60]. Asphyxia and severe chemical bronchopneumonia have resulted from exposures to high concentrations of sulfur dioxide in confined spaces [131]. Evidence that lung cancer is associated with inhalation of coke oven emissions and coal tar products has also been presented in NIOSH criteria documents [17,18]. Silicosis, a pulmonary fibrosis, is caused by inhalation and pulmonary deposition of free silica [129].

In the absence of respiratory symptoms, physical examination alone may not detect early pulmonary illnesses in workers. Therefore, screening tests are recommended. These should include a chest X-ray examination performed initially and thereafter at the physician's discretion and pulmonary function tests, ie, forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1).

(5) Blood

On the basis of evidence that benzene is leukemogenic, NIOSH [132] recommended that benzene should be considered carcinogenic in man. For workers exposed to benzene, a complete blood count (CBC) is recommended as a screening test for blood disorders. This includes determination of hemoglobin (Hb) concentration, hematocrit, red blood cell (RBC) count, reticulocyte count, white blood cell (WBC) count, and WBC differential count.

(6) Central Nervous System

CNS damage can be caused by carbon disulfide, carbon monoxide, cresol, and lead, as indicated by NIOSH criteria documents on those chemicals [58,127,128,133]. Following a substantial exposure to any CNS toxicant, or if signs or symptoms of CNS effects occur or are suspected, a complete neurologic examination should be performed.

(7) Cardiovascular

Carbon disulfide has been suggested to have an effect on the cardiovascular system [128]. Recommended medical surveillance emphasizes cardiovascular evaluation, including an electrocardiogram (ECG) [128]. Deleterious myocardial alterations such as restricted coronary blood flow may occur in workers with chronic heart disease who are exposed to carbon monoxide [58].

The medical history will help to identify workers with a family history of heart problems.

(b) Exposure Monitoring

Industrial hygiene monitoring is used to determine whether employee exposure to chemical and physical hazards is within the limits set by OSHA or recommended by NIOSH (see Appendix V) and to indicate where corrective measures are needed if exposure exceeds those limits. There are no established exposure limits for many substances that may contaminate the workplace air in coal liquefaction plants. In these circumstances, exposure monitoring can still serve two purposes. First, failures in engineering controls and work practices can be detected. Second, data can be developed to help identify causative agents for effects that may be revealed during medical monitoring. It is not possible at this time to predict which individual chemicals may have the greatest toxic effect. Furthermore, the possible interaction of individual chemicals must be considered.

NIOSH has published an Occupational Exposure Sampling Strategy Manual [134] to provide employers and industrial hygienists with information that can help them determine the need for exposure measurements, devise sampling plans, and evaluate exposure measurement data. Although this manual was specifically developed to define exposure monitoring programs for compliance with proposed regulations, the information on statistical sampling strategies can be used in coal liquefaction plants. Guidelines are also provided for selecting employees to be sampled, based on identification of maximum risk employees from estimated exposure levels or on random sampling when a maximum risk worker cannot be selected.

The manual [134] suggests that a workplace material survey be conducted to tabulate all workplace materials that may be released into the atmosphere or contaminate the skin. All processes and work operations using materials known to be toxic or hazardous should be evaluated.

Many of the materials present in coal liquefaction plants are complex mixtures of hydrocarbons, which may occur as vapors, aerosols, or particulates. It would be impractical to routinely quantitate every component of these materials. For many materials, measuring the cyclohexane-soluble fraction of total particulate samples would yield useful data for evaluating worker exposure. Chemical analysis procedures developed for coal tar pitch volatiles can be readily applied to coal liquefaction materials, and comparison of data from other industries would be possible. However, this does not imply that the PEL of 0.15 mg/m^3 of benzene-soluble coal tar pitch volatiles established for coke oven emissions is a safe level for coal liquefaction materials. Instead, monitoring results should be interpreted with toxicologic data on specific coal liquefaction materials, including products, intermediate process streams, and emissions.

Several additional exposure monitoring techniques have been suggested for consideration in specific plants.

(1) Indicator Substance

The use of an indicator substance for monitoring exposures has been suggested by several sources [16,37,135]. An indicator is a chemical chosen to represent all or most of the chemicals that may be present. Ideally, an indicator should be (1) easily monitored in real time by commercially available personal or remote samplers, (2) suitable for analysis where resources and technical skills are limited, (3) absent in ambient air at high or widely fluctuating concentrations, (4) measurable without interference from other substances in the process stream or ambient air, and (5) a regulated agent so that the measurements serve the purposes of quantitative sampling for compliance and of indicator monitoring [16]. Indicators mentioned in the literature include carbon monoxide [16], benzo(a)pyrene [37,136], PAH's [136], 2-methylnaphthalene [1], and hydrogen sulfide [16].

Although indicator substances may be useful in coal gasification plants [16], this monitoring method is not recommended for coal liquefaction because interpretation of results may be misleading. Exposures to complex mixtures of aerosols, gases, and particulates may occur in coal liquefaction, but when indicator substances are used, quantification of employee exposure to agents other than the indicator cannot be determined. For example, in one plant [38], chemical analysis of nearly 200 particulate samples for benzene-soluble material did not reveal any consistency in the ratio of the mass of benzene-soluble constituents to the total mass concentration. An additional drawback is that this method provides a hazard index only for contaminants in the same physical state as the indicator substance. For example, carbon monoxide acts as an indicator only for other gases and vapors, not for particulates. An indicator substance approach may be useful for planning a more comprehensive exposure monitoring program and for identifying emission sources of coal-derived materials, but not for evaluating employee exposure.

(2) Alarms for Acutely Toxic Hazards

White [135] suggested monitoring substances or hazards that could immediately threaten life and health, such as hydrogen sulfide, carbon monoxide, nitrogen oxides, oxygen deficiency, and explosive hazards. Recommendations for hydrogen sulfide alarms have been published by NIOSH [65] and should be adopted where the possibility exists for high concentrations of hydrogen sulfide to be released.

(3) Ultraviolet Fluorescence

Based on the toxic effects described in Chapter III, skin contamination must be considered an important route of entry for exposure to toxic substances. Skin contamination can occur by direct contact with a chemical or by contact with contaminated work surfaces. Studies are currently being conducted [1,137] to develop instrumentation to quantitate specific PAH constituents in surface contamination using a sensor that detects fluorescence at specific wavelengths. Existing methods are based on fluorescence when illuminated by broad-spectrum UV lamps. Methods based on fluorescence have been recommended for monitoring PAH's in surface contamination [138,139]. However, this test is insensitive to specific chemical compounds that may be carcinogenic. Possibly harmless fluorescent materials are detected, while nonfluorescing carcinogens are not.

Although UV light has been used in several plants to detect skin contamination [1], there is concern about the risk of skin sensitization and promotion of carcinogenic effects. In the criteria document on coal tar products, the potential for photosensitive reactions in individuals exposed concurrently to UV radiation and coal tar pitch was discussed. UV radiation at 330-440 nm, but not at 280-320 nm, in combination with exposure to coal tar pitch was found to induce a photosensitive reaction evidenced by erythema and wheal formation [17].

In one plant, a booth to detect skin contamination has been constructed for use by employees [1]. This booth operates at 320-400 nm with an approximate exposure time of 15-30 seconds. A person standing inside the booth under UV light can observe fluorescent material on the body by looking into mirrors on all four walls [1]. This enables the worker to detect contamination that might otherwise go unnoticed. Contamination may occur from sitting or leaning on contaminated surfaces or from not washing hands before using sanitary facilities. When the booth is used, eye protection is required, and employees are instructed to keep exposure time to a minimum [1]. Because of the possible risk associated with excessive use of a UV booth, UV examination for skin contamination should only be conducted under medical supervision for demonstration purposes, preferably with hand-held lamps.

At present, no suitable method for quantitative measurement of surface contamination has been developed. Skin contamination was recorded by the medical personnel in one plant [1] who used contour marking charts and rated fluorescent intensity on a subjective numeric scale. This method of estimating and recording skin contamination could provide a useful indication of such exposure. Some preliminary work [39] has been completed to develop a method for analyzing skin wipe samples from contaminated skin. Analysis of contaminants extracted from 5-cm gauze pads wetted with 70% isopropyl alcohol showed that benzene-soluble materials can be recovered from the skin surface; wipe samples of contaminated skin contained 10 times more benzene solubles than did wipe samples from apparently clean skin [39].

(4) Baseline Monitoring

One company has developed a system of baseline monitoring for coal-derived materials in its coal conversion plants [140]. In this system, detailed comprehensive area and personal monitoring is conducted. The baseline data obtained are used to select a representative group of area sites and people (by job classification) to be monitored periodically. Changes can be noted by comparing the results over time. Baseline monitoring should be repeated quarterly [140]. When this technique is used, chemicals representative of the process should be chosen and monitored in places where they are likely to be emitted.

(c) Recordkeeping

In previous sections of this chapter, monitoring of worker health and the working environment is recommended as an essential part of an occupational health program. These measures are required to characterize the workplace and the exposures that occur there and to detect any adverse health effects resulting from exposure. The ability to detect potential occupational health problems is particularly critical with a developing technology such as coal liquefaction, where exposures to sulfur compounds, toxic trace elements, coal dust, PAH's, and other organic compounds result in an occupational environment that is most difficult to characterize. Actions taken by the industry to protect its workers and by government agencies to develop regulations must be based on data that define and quantify hazards. Because coal conversion is a developing technology, it is also particularly appropriate to recommend that certain types of occupational health information be collected and recorded in a manner that facilitates comprehensive analysis.

This need for a recordkeeping system that collects and analyzes occupational health data has resulted in a proliferation of methods being adopted, usually on a company-by-company basis [141,142]. There is a need for standardized recordkeeping systems for use by all coal liquefaction plants that will permit comparisons of data from several sources [143]. Accordingly, those engaged in coal liquefaction should implement a recordkeeping system encompassing the following elements:

(1) Employment History

Each employee should be covered by a work history detailing his job classifications, plant location codes, and to the extent practical, the time spent on each job. In addition, compensation claim reports and death certificates should be included.

(2) Medical History

Each employee's medical history, including personal health history and records of medical examinations and reported illnesses or injuries, should be maintained.

(3) Industrial Hygiene Data

All results of personal and area samples should be recorded and maintained in a manner that states monitoring results, notes whether personal protective equipment was used, and identifies the worker(s) monitored or the plant location code where the sampling was performed. An estimate of the frequency and extent of skin contamination by coal-derived liquids should be recorded annually for each employee.

Emergency Plans and Procedures

(a) Identification of Emergency Situations

The key to developing meaningful and adequate emergency plans and procedures is identification of hazardous situations that require immediate emergency actions to mitigate the consequences. In most chemical industries, hazards such as fires, explosions, and release of and exposure to possibly toxic chemicals have been identified, and adequate safety, health, and emergency procedures have been developed [1,112,113,144,145]. In addition, chemical and physical characteristics of materials processed in coal liquefaction plants present additional health and safety hazards, as discussed in Chapter III. These hazards should be formally addressed in the development of emergency plans and procedures. Some failure mechanisms could result in situations requiring emergency actions, eg, rupture of high-pressure lines due to thinning by erosion and corrosion, and rupture of lines during the use of high-pressure water to clear blockage resulting from the solidification and plugging of coal solutions. System safety analyses can be used to identify possible failures or hazards expected during plant operation.

(b) Emergency Plans and Procedures for Fires and Explosions

Prior to plant operation, emergency plans and procedures for fires, explosions, and rescue should be developed, documented, and provided to all appropriate personnel. The plans should formally establish the organization and responsibilities of a fire and rescue brigade, identify all emergency personnel and their locations, establish training requirements, and establish guidelines for the development of the needed emergency procedures. They should follow the guidelines in 29 CFR 1910, Subpart L, Fire Protection, Means of Egress, Hazardous Materials. Regulations contained in the Energy Research and Development Administration (ERDA) Manual, Chapter 0601, "Emergency Planning Preparedness and Response Program, 1977," [146] should also be used as guidelines for developing the emergency plan.

Training of emergency personnel should also follow the guidelines in 29 CFR 1910, Subpart L, with special attention given to systems handling coal-derived materials and any special procedures associated with these systems. Special firefighting and rescue procedures, protective clothing requirements, and breathing apparatus needs should be specified for areas where materials might be released from the process equipment during a fire or explosion. These procedures should be documented and incorporated into standard operating procedures, and copies of these documents should be provided to all emergency personnel.

Emergency services should be adequate to control such situations until community-provided emergency services arrive. Where a large fire department is staffed with permanent, professionally trained employees and has developed adequate training programs, it would be appropriate for a plant manager to rely more on the emergency services of that department. When local community services are relied upon for emergency situations, the emergency plan discussed above should include provisions for close coordination with these services, frequent exercises with them, and adequate training in the potential hazards associated with the various systems in the plant.

(c) Emergency Medical Treatment

It is important to identify the hazardous materials associated with coal liquefaction and the medical treatment necessary. In their operating and safety procedures, plants have documented recognized and established first-aid and medical treatment for various chemical exposures [1,112,113,144,145]. The first-aid program should comply with the requirements in 29 CFR 1910.151.

Emergency medical personnel, such as nurses or those with first-aid training, should be at the plant at all times. Immediate response is needed when life would be endangered if treatment were delayed, eg, the inhalation of toxic gases such as hydrogen sulfide or carbon monoxide, and asphyxiation due to oxygen displacement by inert gases such as nitrogen.

Each coal liquefaction plant should develop fire, rescue, and medical plans and procedures addressing all hazards associated with the handling of coal liquefaction materials. Fire, rescue, and medical services should be provided that are capable of handling and controlling emergencies until additional community emergency services can arrive at the plant site. The emergency personnel at the plant should direct all emergency actions performed by outside services.