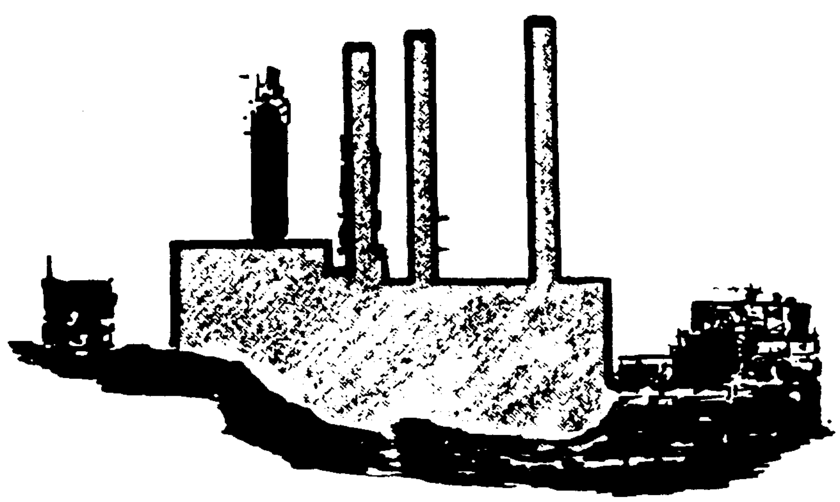
NIOSH

OCCUPATIONAL HAZARD ASSESSMENT

COAL LIQUEFACTION, Volume I - Summary



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

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Volume I - Summary

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PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need to protect the health and safety of workers occupationally exposed to an ever-increasing number of potential hazards. Consequently, the National Institute for Occupational Safety and Health (NIOSH) has implemented a program to evaluate the adverse health effects of chemical and physical agents and industrial processes. This summary of NIOSH's Occupational Hazard Assessment of Coal Liquefaction is a result of that program. By addressing the hazard while direct coal liquefaction technology is still being developed, the risk of potential adverse health effects can be substantially reduced in both experimental and commercial plants.

While the occupational hazard assessment, Volume II, is a critical, lengthy review of the scientific and technical information available and discusses the occupational safety and health issues of pilot plant operations, this summary document presents the highlights in a shorter, more useable form for a wider audience. Both documents are intended for use by workers, industry, trade associations, government agencies, scientific and technical investigators, and the public; those interested in a more thorough and detailed discussion should read the Occupational Hazard Assessment of Coal Liquefaction. The information and recommendations presented should facilitate development of specific procedures for hazard control in individual workplaces by persons immediately responsible for health and safety. NIOSH will periodically update and evaluate new data and information as they become available and, at the appropriate time, will consider proposing recommendations for a standard to protect workers in commercial coal liquefaction facilities.

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SYNOPSIS

The coal liquefaction process converts coal into hydrocarbon products. In doing so, it both uses and produces toxicants potentially hazardous to worker health. The toxicants are varied, ranging from simple chemicals to complex mixtures or organic carcinogens. The possible health effects are also varied. Animal studies have demonstrated that some of the process chemicals have produced tumors at the site of application. Some workers may be exposed by inhalation of gases, vapors, or airborne particles, skin contact with airborne material, contact with contaminated surfaces, or accidental ingestion. Some of these same chemicals have caused severe long-term effects such as skin and lung cancer in workers in similar industries. Other potential adverse health effects may include fatal poisoning from inhalation, severe respiratory irritation, and chemical burns. Fires and explosions can also occur.

This document is designed to provide information that can be used to guard against these potential adverse health effects. Measures such as engineering controls, specific work practices, personal protective equipment, medical surveillance and exposure monitoring, recordkeeping, and emergency plans and procedures are recommended.

ACKNOWLEDGEMENTS

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INTRODUCTION

Coal liquefaction is a process that converts coal into hydrocarbon products. Most often, the major products are condensed aromatic liquids, with some gases and solids also produced, pending on operating conditions and the type of coal and process used. Liquefaction is accomplished by breaking the chemical and physical bonds of the coal in the presence of a hydrogen source. The four major coal liquefaction processes are: (1) pyrolysis, in which the coal is heated in the absence of oxygen, and hydrogen is abstracted from coal hydrogen donors; (2) solvent extraction, which is performed at high temperatures and pressures in the presence of hydrogen and a solvent; (3) direct hydrogenation, in which the coal slurry is hydrogenated in contact with a catalyst under high pressure and temperature; and (4) indirect liquefaction, in which the coal is gasified with steam and oxygen and then catalytically converted to liquid products. This assessment is concerned with direct liquefaction, ie, processes 1-3.

In the United States, coal liquefaction technology is only beginning to develop. It currently consists of a small number of process development units (PDU) for establishing process feasibility and pilot plants. Processing capacities range from less than 5 tons per day (4.5 Mg/d) for the PDU's up to 600 tons per day (544 Mg/d) for the pilot plants. These pilot plants are primarily a testing ground for determining optimum operating conditions for future commercial plants. Previous projections based on plans for development of synthetic fuel technology show that as many as 12 commercial-sized liquefaction plants may be operating by 1995 (assuming each produces approximately 50,000 bbl/d). Collectively, these plants are likely to employ more than 12,000 workers [1]. An increased number of coal miners must also be considered part of the total impact of coal liquefaction technology on occupational safety and health.

In addition to evaluating health effects, this summary document recommends engineering controls, work practices, personal protective equipment and clothing, medical surveillance, and exposure monitoring to reduce the health risks and provide for increased worker safety in coal liquefaction plants. Greater detail is given in the full-length document [2]. NIOSH's recommendations can be used for planning occupational safety and health programs and as a basis for technology development.

In the full-length document on coal liquefaction, the occupational hazards associated with the direct process are thoroughly reviewed. NIOSH has determined that chemicals and physical agents identified in the process could present serious health and safety hazards to the workers in pilot plants and in future commercial plants unless precautions are taken.

One serious health hazard associated with coal liquefaction processes is cancer [3-5]. Certain aromatic amines and polycyclic hydrocarbons measured at two pilot plants investigated by NIOSH are known carcinogens or co-carcinogens [6]. In addition, coal liquefaction materials applied to the skin of laboratory animals have produced cancerous growths [7-10]. Coal liquefaction materials have also caused adverse reproductive effects in laboratory animals [11,12].

A number of other chemicals found in coal liquefaction processes may adversely affect the respiratory and nervous systems, as well as the blood, liver, and kidneys.

HEALTH EFFECTS

Because coal liquefaction is an emerging industry, the opportunity for epidemiologic investigation has been limited to evaluation of worker medical surveillance programs in pilot plants. In 1960 Sexton [13] suggested that workers exposed to coal liquefaction materials have an incidence of cancerous and precancerous skin lesions greater than expected in a similar population not occupationally exposed to the same hazard. In spite of a number of limitations in this study (including a small number of exposed workers, no appropriate comparison population, and a lack of information concerning work histories, medical histories, and exposure levels), the excess incidence of cancerous and precancerous skin lesions reported would still be sufficient to cause concern. Two other reports [14,15] demonstrate that the most common medical problems at pilot plants have been dermatitis, eye irritation, and thermal burns. Although there are limitations in the epidemiologic data available on coal liquefaction, there are strong implications from animal toxicologic and human epidemiologic studies on analogous compounds that certain agents in the coal liquefaction process pose serious health hazards. Such examples include chemical agents found in coal tar products [16] and coke oven emissions [17]. Therefore, every possible precautionary measure should be taken to protect the worker.

Processing of abrasive slurries, particularly at high temperatures and pressures, accelerates erosion and corrosion that may cause leaks in process equipment. Leaks increase the potential for worker skin contact with process materials, inhalation exposure, burns, and fires. In gas handling systems, leaks increase the possibility of worker exposure to high, and potentially fatal, levels of carbon monoxide and hydrogen sulfide. Because coal liquefaction processes operate above the autoignition temperature of many process materials, leaks could result in immediate fires. Furthermore, many process materials are explosive, and leaks may result in a mixture that exceeds its lower explosive limit. This could result in an explosion.

The following paragraphs describe specific health effects. Some guidance is given on elements of the appropriate physical examinations and laboratory tests.

Skin Effects

NIOSH has previously reported on some chemicals that are similar to those in coal liquefaction processes and that affect the skin. For example, creosote has caused keratitis, and crude naphtha, creosote, and residual pitch have caused skin cancer [16]. These materials can also inflame hair follicles and sebaceous glands. Cresol causes a burning sensation, erythema, localized anesthesia, and a brown discoloration of the skin upon contact [18]. NIOSH has also described skin effects as major concerns in workers exposed to carbon black process materials [19], refined petroleum solvents [20], coke oven emissions [17], and phenol [21].

Skin sensitization may occur after skin contact with or inhalation of many different chemicals. Patch testing should be used as a diagnostic aid only after a worker has symptoms of skin sensitization. Patch tests must not be used as a preplacement or screening technique, because they may cause sensitization; medical history and physical examination are much safer ways of estimating whether a worker is sensitized.

Skin lesions should be monitored, and written and photographic records of their development should be made and kept. If lesions change, the worker should be referred to a dermatologist.

Liver Effects

NIOSH has previously concluded that exposure to cresol may result in damage to the liver and that medical surveillance with emphasis on any preexisting liver disorder should be conducted on workers exposed to cresol [18]. Because of the vast reserve functional capacity of the liver, acute hepatotoxicity or severe cumulative chronic damage may occur before recognizable symptoms appear. These symptoms include nausea, vomiting, diarrhea, weakness, general malaise, and jaundice. Numerous screening tests for liver dysfunction exist; those most frequently used are serum bilirubin, serum glutamic-oxaloacetic transaminase (SGOT), serum glutamic-pyruvic transaminase (SGPT), gamma glutamyl transpeptidase (GGTP), and isocitric dehydrogenase.

Kidney Effects

NIOSH has previously concluded that exposure to cresol [18], carbon disulfide [22], coke oven emissions [17], and coal tar products [16] can result in impaired renal function. Renal function impairment can be screened by urinalysis augmented by more specific tests.

Respiratory System Effects

Inhalation of chemicals in coal liquefaction plants may result in damage to the respiratory system. For example, sulfur dioxide and ammonia are respiratory tract irritants, and substantial exposures to ammonia can produce chronic bronchitis, laryngitis, tracheitis, bronchopneumonia, and pulmonary edema [23]. Exposure to sulfur dioxide can cause asphyxia and severe chemical bronchopneumonia [24]. Inhalation of coke oven emissions and coal tar products can lead tc chronic lung disease, including cancer [16,17]. Inhalation and pulmonary deposition of free silica can cause silicosis, a form of pulmonary fibrosis. If a worker does not have symptoms of respiratory distress, physical examination alone may not detect early pulmonary illness. Therefore, a chest X-ray examination is recommended at the time of employment and thereafter at the discretion of the physician. In addition, pulmonary function tests, ie, forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV 1), are also recommended screening tests.

Blood Effects

Because exposure to benzene has been linked with leukemia [25], workers exposed to it should have a complete blood count (CBC) as a screening test for blood disorders. A CBC includes determination of hemoglobin (Hb) concentration, hematocrit, red blood cell (RBC) count, reticulocyte count, white blood cell (WBC) count, and WBC differential count.

Central Nervous System Effects

Cresol [18], carbon disulfide [22], carbon monoxide [26], and lead [27] can damage the central nervous system (CNS). If a worker is substantially exposed to any CNS toxicant, or if signs or symptoms of CNS effects occur or are suspected, a complete neurologic examination should be performed.

Cardiovascular System Effects

Carbon disulfide has been suggested to have an effect on the cardiovascular system [22]. Recommended medical surveillance emphasizes cardiovascular evaluation, including an electrocardiogram (ECG). Deleterious myocardial alterations such as restricted coronary blood flow may occur in workers with chronic heart disease who are exposed to carbon monoxide [26].

Medical Surveillance

Medical monitoring is essential to protect workers in coal liquefaction plants from adverse health effects. To be effective, medical surveillance should be both well timed and thorough to detect adverse effects on worker health as early as possible. Thoroughness in medical surveillance is necessary because of the many chemical and physical agents a worker may be exposed to. Worker exposure is not predictable; it can occur whenever any closed process equipment accidentally leaks, vents, or ruptures. Not all adverse effects of exposure in coal liquefaction plants are known, but most of the major organs (the liver [18], kidneys [22], lungs [28], heart [26], and skin [20]) may be affected.

Medical surveillance should consist of preplacement, periodic, and termination examinations. Preplacement examinations set a baseline for the worker's general health and for specific tests, eg, future audiometric tests. During these examinations, a worker's physical ability to perform his job while using a respirator can be determined. These examinations can also detect some preexisting conditions that may be aggravated by, or make the worker more vulnerable to, the hazards of coal liquefaction processes. If such a condition is found, the employer should be notified and the worker fully counseled on these hazards.

Periodic examinations allow monitoring of worker health to assess changes resulting from exposure to materials in coal liquefaction processes. Workers should be encouraged to report any change in their health to the medical department; self-examination is important to health monitoring. Periodic examinations should be performed at least annually. Physical examinations of workers prior to termination of employment will provide complete information to the worker and to the medical surveillance program.

All three types of examinations should be comprehensive and include medical and work histories, physical examinations, and special tests. Medical histories should focus on preexisting disorders. Work histories are important because past exposures may predispose the worker to adverse effects; for example, past exposure to coal-derived products may have caused sensitization.

Physical examinations should be thorough and some clinical tests may be useful as general screening measures. In the screening tests, worker acceptance of tests should be weighed against the information that the test will yield. Physicians should consider the test sensitivity, the seriousness of the disorder, and whether the disorder can result from exposure to coal liquefaction materials. They should choose tests based on their knowledge of exposure-effect relationships, the worker's exposure conditions, and any preexisting factors. If possible, they should choose tests with simple sample collection, processing, and analysis. The physician should ensure that appropriate followup tests and procedures are carried out if test results are abnormal.

Exposure Monitoring

Industrial hygiene monitoring is used to determine whether worker exposure to chemical and physical hazards is within the limits set by OSHA or recommended by NIOSH or other voluntary standard-setting organizations, and to indicate where corrective measures are needed. However, no exposure limits have been established for many substances that may contaminate the workplace air in coal liquefaction plants. Exposure monitoring is necessary where exposure to suspect cancer-causing agents or other toxic materials might occur. For these substances, exposure monitoring is important because it can spot failures in engineering controls and work practices, and produce data that can be used to develop exposure-effect relationships. It is not possible now to predict all of the chemicals in coal liquefaction plants that may have toxic effects. In addition, the possible interactive effects of individual chemicals should be considered when designing the monitoring program.

A workplace material survey should be conducted to tabulate workplace materials that may be released into the atmosphere or may contaminate the skin. Guidelines for sampling and analysis may be found in NIOSH's Occupational Exposure Sampling Strategy Manual [29], the NIOSH Manual of Analytical Methods [30-32], and OSHA's Industrial Hygiene Field Operations Manual [33]. All processes and work operations using materials known to be toxic or hazardous should be evaluated.

Many materials in coal liquefaction plants are complex mixtures of hydrocarbons occurring as vapors, aerosols, or particulates. Although it is impractical to measure each component of the mixture, measuring the cyclohexane-extractable fraction of total particulate samples will yield data useful for evaluating worker exposure. Chemical analysis procedures developed for coal tar pitch volatiles can be applied to coal liquefaction materials. However, one must not infer that the permissible exposure limit (PEL) of 0.15 mg/cu m for the benzene-soluble fraction of total particulate matter during the carbonization of coal, established for coke oven emissions, is safe for workers in coal liquefaction plants. Instead, monitoring results should be interpreted with toxicologic data on specific, or mixtures of coal liquefaction materials.

Alarms should be installed to monitor substances or hazards that could immediately threaten life and health, such as hydrogen sulfide, carbon monoxide, oxygen deficiency, and potential explosive hazards. NIOSH has published recommendations for the use of hydrogen sulfide alarms [34], which should be installed in areas where high concentrations of hydrogen sulfide may be released. NIOSH also recommends that alarms be developed for other gases where life-threatening exposures could occur.

Recordkeeping

Monitoring worker health and the working environment is essential in an occupational health program. Coal liquefaction is a developing technology, with many hazards still unknown. Recordkeeping is particularly critical to this technology, where the occupational environment is difficult to characterize. Standardization of the recordkeeping systems is recommended because it will allow easy cross-comparison of data from similar plants and thereby facilitate a more comprehensive examination of the hazards in the industry as a whole [35]. Therefore, coal liquefaction plants should have a system that records at least the following information.

(a) Employment History

For each worker there should be a work history detailing job classifications, plant location codes, and time spent on each job. Compensation claim reports and death certificates should be included.

(b) Medical History

A medical history comprising personal health history, medical examination records, and reported illnesses and injuries should be maintained for each worker.

(c) Industrial Hygiene Data

Records should be kept of personal and area sampling that state monitoring results, note whether personal protective equipment was used, and identify worker(s) monitored or plant location codes for areas where sampling was performed. Estimates of the frequency and extent of skin contamination by coal-derived materials should be recorded annually for each worker.

Engineering controls of workplace hazards can be applied to both pilot and commercial plants. Engineering design for demonstration coal liquefaction plants is currently in the developmental stage, and it should emphasize prevention of worker exposure by ensuring process containment, limiting worker exposure during maintenance, and providing for equipment reliability. The effects of erosion, corrosion, and failure of seals, valves, and other process components should be minimized. Design and quality control of pressure vessels should ensure reliability of vessel integrity. Pressure safety and release valves must be designed according to well-established engineering practices and located so that operating personnel are not exposed to releases. Control rooms should be structurally designed to protect operating personnel and should remain functional in an accident. Process sampling equipment should be designed to minimize the release of process material. Many of the engineering design considerations discussed in this and the full-length document are addressed in existing standards, codes, and regulations [2].

A formal system safety program should be initiated to provide for early recognition of safety problems, analysis of design, identification of potential hazards, and specification of safety controls and procedures. At a minimum, the safety program should include:

(1) Scheduled reviews and analyses;
(2) Review responsibilities of designated workers;
(3) Required methods of analyses; and
(4) Requirements for documentation and certification.

Before equipment is removed or serviced, it should be isolated from the process stream and flushed and purged where possible. Gas purges should be disposed of by a flare or some other effective method. In areas where flammable materials are collected, the flammable gas and vapor concentration must be maintained at less than its lower explosive limit. If workers enter areas where flammable or toxic materials collect, ventilation must be adequate to maintain safe concentrations.

Workers who sample process streams may be exposed to significant amounts of process material. During plant visits, NIOSH observed workers using a nozzle to direct the material into small cans [14], a technique that could lead to excessive and unnecessary exposures. In other plants, NIOSH observed a safer method and recommends it where practicable: the use of a closed-loop system designed to remove flammable or toxic material from the sampling lines by flushing and purging prior to removing the sampling bomb [14]. These flushings from the sampling lines should be collected and disposed of properly.

To minimize plugging of lines and equipment through coking and solidification of coal slurries, instrumentation and controls should be provided. For example, lines and equipment should be heat-traced to maintain temperatures greater than the pour point of the material. However, sometimes plugging will occur regardless of the preventive measures taken. Under these circumstances, local ventilation and/or respirators should be provided and used to limit exposure to hazardous materials during decoking or hydroblasting. Contaminated water from hydroblasting should be collected, treated, and recycled or disposed of properly. Where practicable, equipment used to handle fluids containing solids should be flushed and purged during shutdown to minimize potential coal slurry solidification or settling of solids.

Thus, proper engineering design and controls must include safeguards specifically designed to protect workers. Good engineering design, when combined with safe operating procedures for full-scale coal liquefaction plants, should provide inherent safeguards. By removing pathways for release of toxic substances to the workplace, the need for minimizing exposures to workers will be reduced, as will reliance on personal protective equipment.

SPECIFIC WORK PRACTICES

There are workplace safety and health programs in coal liquefaction pilot plants similar to programs in petroleum refineries and the chemical industry. Most coal liquefaction pilot plants have written procedures for operational safety practices, including lockout of electrical equipment, tagout of valves, fire and rescue brigades, safe work permits, vessel entry permits, wearing of safety glasses and hardhats, and housekeeping.

Developers of occupational safety and health programs should use (1) the general industry standards specified in the Code of Federal Regulations (29 CFR Part 1910), (2) voluntary guidelines from similar industries, (3) NIOSH recommendations describing specific work practices for similar materials [16,17,20], (4) recommendations from equipment manufacturers, and (5) professional judgment and operating experience.

For engineering controls, supplemental work practices, and personal protective equipment to be effective, employers should ensure that workers are informed of the hazards associated with the materials present, the procedures for handling materials and cleaning up spills, and the use of personal protective equipment and emergency procedures. Where possible, oral instructions should be augmented by written and audiovisual materials to ensure that workers are always aware of the most current procedures and techniques for ensuring their safety and health. In addition, worker comprehension of instructions should be evaluated.

Operating Procedures

Procedures are being developed for coal liquefaction pilot plants for each phase of operation, including startup, normal operation, routine maintenance, normal shutdown, emergency shutdown, and shutdown for extended periods. Provisions should be made in these procedures for safely storing process materials, preventing solidification of dissolved coal, cleaning up spills, and decontaminating equipment that requires maintenance. Preventing leaks is a major problem during startup of high pressure coal liquefaction systems; therefore, systems should be gradually pressurized and checked for leaks, especially at valve outlets, blinds, and flanges. Recently repaired, serviced, or replaced equipment should be carefully examined. If no leaks are found, the system should be slowly brought up to operating pressure and temperature. If leaks occur, appropriate repairs should be made.

Equipment that operates at high pressures should be routinely inspected to determine maintenance needs. Intervals should be established for monitoring and replacing equipment susceptible to erosion and corrosion. Monitoring requirements, schedules, and replacement intervals should be part of a quality assurance program.

Confined Space Entry

NIOSH has made recommendations that are generally applicable to entry in confined spaces in coal liquefaction facilities [36]. These recommendations pertain to entry permits, testing work atmospheres, monitoring, medical surveillance, personnel training, labeling and posting, preparations such as isolation, lockout, tagout, purging, and ventilation, safety equipment and clothing, rescue equipment, and recordkeeping. One coal liquefaction facility visited by NIOSH recommends an air changeover rate of six times per hour during entry and work in confined spaces.

Restricted Areas

Access should be controlled at coal liquefaction plants to prevent entry by persons unfamiliar with the hazards present, the precautions necessary, and the plant emergency procedures. Access at one coal liquefaction facility is controlled by using warning signs, red lights, and barriers [37]. Because this facility is small, the use of doors as physical barriers is feasible for access control. Fences and gates serve a similar purpose in larger operations. Employers should keep a log of workers entering restricted areas to provide a record of who is exposed in high risk operations. A visitors' log would aid in accounting for people at the plant in an accident or emergency. Visitors should be informed of the hazards, necessary precautions, and emergency procedures.

Spill Decontamination

Spills of toxic liquids should be cleaned up at the earliest safe opportunity. Equipment should be designed to ensure that spills and leaks will be contained with a minimum of worker exposure. Small spills may be contained by a sorbent; spent sorbent should then be disposed of in a safe manner. If spills must be removed by hand, only workers who are instructed and trained in safe decontamination and disposal procedures should supervise and perform cleanup. Employers must supply appropriate personal protective equipment and ensure that workers understand how to use it.

Dried tar is difficult to remove from surfaces. For this reason, easily strippable coatings may be used where tar may spill. Because such coatings do not adhere well, the tar can be removed with the coating. The clean surface can then be recoated. In some plants, where such coatings are not used, manual scraping and chipping, commercial cleansers, or steam have been used [38]. These methods further increase the hazard to cleanup personnel. For example, steam stripping may generate airborne contaminants, as well as increase the potential for burns. For these reasons, steam stripping is discouraged. Where organic solvents are used for cleanup, special care is necessary to limit exposure to solvent vapors and aerosols. This may include the use of local ventilation and approved respirators.

Hand tools and portable equipment may be contaminated and should be cleaned before reuse. They can be steam-cleaned in an enclosed system or cleaned by vapor degreasing and ultrasonic agitation. The residue should be contained and disposed of properly, and solvents should be well controlled.

Personal Hygiene

Where engineering controls are inadequate to prevent exposure, workers should be extremely alert to the potential hazards of direct contact with coal-derived products. They must exercise good personal hygiene by (1) avoiding touching their faces, genitals, or rectal areas without first washing their hands; (2) washing skin with soap and water after direct contact with coal-derived products; and (3) washing their hands, forearms, face, and neck after completing each operation where there was known or suspected contact with coal-derived products. Workers must also be alert to sores that do not heal properly, dead skin, and changes in warts and moles. All suspicious lesions should be reported immediately to the medical department because they may be early signs of cancer.

To ensure good personal hygiene in plants, workers must take showers at the end of each shift. Workers should thoroughly wash their hair and hairline during showers and should carefully clean skin creases and fingernails. Double locker rooms are also necessary to segregate contaminated clothing from street clothing. Employers should provide an adequate number of washrooms throughout the plant and encourage their use. Washrooms should be close to lunchrooms so workers can wash before eating. Employers should ensure that lunchrooms remain uncontaminated to minimize the likelihood of inhalation or ingestion of coal-derived products. Employers should require workers to remove contaminated protective clothing and wash before entering the lunchroom. Bar soap should be provided in all plant showers, and lanolin-based or equivalent waterless hand cleaners should be provided in all plant washrooms and in the locker facility. Organic solvents should not be used, because they may cause the contaminants to further penetrate the skin and they are inherently toxic in many cases.

PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

Design of coal liquefaction plants must focus on engineering controls to effectively minimize worker exposure to coal-derived products. In those instances where engineering controls do not provide adequate protection (mechanical breakdown, for example), good work practices become the primary means of safeguarding health. If the work practices are also inadequate and workers are directly exposed to coal-derived products, it may be necessary to use personal protective equipment and clothing.

Respiratory Protection

Use of respirators for protection is acceptable only when engineering controls and standard work practices are impractical and cannot be improved. Because coal liquefaction is a fledgling industry, there should be few circumstances where equipment needs to be retrofitted to improve engineering control. Ideally, equipment should be initially designed to provide adequate control. However, if design is inadequate and engineering controls do need to be installed after plants are in operation, respirators must be used until engineering controls are in effect. Other circumstances during which respirators may be necessary for short periods include maintenance, emergencies, leaks, spills, and fires.

When respirators are used, they should reduce inhalation and ingestion of airborne contaminants and provide life support in oxygen-deficient atmospheres. Although respirators are useful for reducing exposure to hazardous materials, they have several undesirable aspects. Problems associated with using respirators include poor communication and hearing, reduced field of vision, increased fatigue and reduced worker efficiency, strain on heart and lungs, skin irritation or dermatitis caused by perspiration or facial contact with the respirator, and discomfort. Medical screening should be conducted to determine a worker's ability to wear a respirator. Facial fit is crucial for effective use of most negative pressure respirators, because if leaks occur, air contaminants may be inhaled. Facial hair, such as beards or long sideburns, and facial movements can prevent good respirator fit; therefore, it is important that careful fit testing be conducted to assure an adequate fit.

Training workers to properly use, handle, and maintain respirators helps to achieve maximum effectiveness of respiratory protection. Minimum training requirements for workers and supervisors have been established by the Department of Labor (29 CFR 1910.134). These requirements include handling the respirator, proper fitting, testing facepiece-to-face seal, and wearing the respirator in uncontaminated workplaces during a long trial period. This training should enable the worker to determine whether the respirator is operating properly by checking it for cleanliness, leaks, proper fit, and spent cartridges or filters. Employers should impress upon workers that respiratory protection is necessary if engineering controls are not sufficient.

Respirator facepieces need to be maintained regularly to remove contamination and to slow down the aging of rubber parts. Employers should consult the manufacturers' recommendations on cleaning methods, and care should be taken not to use solvents that may deteriorate rubber parts.

Gloves

Gloves are usually worn at coal liquefaction pilot plants in cold weather, when heavy equipment is handled, and in areas where there is hot process equipment. 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 pilot plants, including cotton mill gloves, vinyl-coated heavy rubber gloves, and neoprene rubber-lined cotton gloves.

No quantitative data on glove penetration by coal liquefaction materials have been reported. One should assume, however, that gloves and other protective clothing do not provide complete protection against skin contact. To prevent contamination of glove linings, workers should wash their hands before putting on gloves. Because penetration by toxic chemicals may occur in a relatively short time, gloves should be discarded following noticeable contamination.

Work Clothing and Footwear

Work clothing and footwear can reduce exposure to coal-derived products, especially 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, T-shirts, underpants, and cotton socks; 3 jackets; and 1 rubber raincoat [39]. In another facility, thermal underwear for use in cold weather was provided [14]. Work clothing, including workshoes and hardhats, should be changed at the end of every workshift or as soon as possible when contaminated.

All work clothing and footwear should be left at the plant at the end of each workshift, and the employer should be responsible for handling and laundering the garments. Because of the volume of laundry involved, on-site 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 have been adopted.

Hearing Protection

In certain instances, engineering controls will not be adequate, and exposure-to-noise levels exceeding the NIOSH-recommended limit (85 dBA for an 8-hour period) may occur in some areas. Under these circumstances, workers should be provided with protective devices to prevent hearing loss.

There are two basic types of hearing protectors available: earmuffs that fit over the ear and earplugs that are inserted into the ear. Workers should choose the type of hearing protector they want to wear. Some workers may find earplugs uncomfortable, and others may be unable 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, use, and cleaning of hearing protectors. The program should also evaluate the need for protection against noise in various areas of the plant and provide the workers with a choice of hearing protectors suitable for those areas. Workers should be cautioned not to use earplugs that are contaminated with coal liquefaction materials.

Eye and Face Protection

Eye and face protection, such as safety glasses and faceshields, should be provided for and worn by all workers engaged in activities in which hazardous materials may contact the eyes or face. In addition, full-length plastic faceshields should be worn in areas where contact with tar or tar oil is likely, except when full-facepiece respirators are being worn.

EMERGENCY PLANS AND PROCEDURES

During the design of the plant and before operation, emergency plans and procedures for fires, explosions, and rescue should be developed and given to all appropriate personnel. The plans should establish the organization and responsibilities of a fire and rescue brigade, name all emergency personnel and their locations, state training requirements, and give guidelines for developing emergency procedures. The guidelines should follow the rules published in the Federal Register, Fire Protection, Means of Egress, Hazardous Materials, Final Rule (September 12, 1980). Regulations contained in a manual of what now the Department of Energy (DOE) Chapter 0601, Emergency Planning Preparedness and Response Program [40], should also be used as guidelines for developing the emergency plan.

Emergency personnel should also be trained according to guidelines in 29 CFR 1910, Subpart L, giving special attention to systems handling coal-derived materials and to any associated special procedures. Information on special firefighting and rescue procedures, protective clothing requirements, and breathing apparatus needs should be distributed for areas where materials might be released from the process equipment during a fire or explosion. These procedures should be incorporated into written standard operating procedures, and copies should be given to all emergency personnel.

Plant emergency services should be adequate to control such situations until community-provided emergency services arrive. Where a community fire department is staffed with permanent, professionally trained workers, a plant manager may rely more on the emergency services of that department. When community services are relied on for emergency situations, the plant emergency plan should include provisions for close coordination with these services, frequent exercises with them, and adequate training in the potential hazards of various systems in the plant.

Emergency medical personnel, such as nurses or those with first-aid training, should be present at the plant at all times. Immediate response is needed when a delay in treatment would endanger life. These cases may involve inhalation of toxic gases such as hydrogen sulfide or carbon monoxide and asphyxiation due to oxygen displacement by inert gases such as nitrogen.

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