## VI. WORK PRACTICES

Good work practices, personal hygiene, and proper training all are essential to control the occupational hazards associated with coal gasification. Employees must be thoroughly trained in the use of all procedures and equipment required in their employment, and all appropriate emergency procedures and equipment. The effective use of good work practices and engineering controls depends on the knowledge and cooperation of employers and employees.

Written instructions informing employees of the particular hazards of specific substances, methods of handling the material, procedures for cleaning up spills, personal protective equipment requirements, and procedures for emergencies must be on file and readily available to employees. Employers must establish programs of instruction to familiarize all potentially exposed employees with these methods, procedures, and requirements.

An extensive preventive maintenance program is essential. Equipment in critical areas should be monitored for reconditioning or replacement at predetermined intervals based on the manufacturers' recommendations or, preferably, on operating experience. Equipment should be scheduled for thorough maintenance checks at appropriate intervals. High-maintenance equipment such as gasifiers must be taken off line periodically for complete cleaning and for the reconditioning or replacement of parts.

For each phase of routine and emergency maintenance or shutdown there should be developed a well-conceived and strictly enforced procedure, including the use of a safe work permit where appropriate (see Figures VI-1 and VI-2) [12]. The permit should include approvals for all facets of protection necessary to conduct the maintenance operation without danger to safety or health and to insure complete physical and electrical isolation of the maintenance area, which may require the use of a portable power supply. Before the start of any maintenance operation, a safety officer and/or shift or maintenance supervisor or the equivalent should complete the permit, detailing all necessary protective procedures. The permits should provide rigid requirements for personal protective equipment, respirators, lock-out and tag-out procedures, equipment isolation, air sampling, and emergency contingencies. A single, comprehensive safe work permit may be used for hot work, vessel or process-line entry, and routine maintenance; alternatively, separate permits may be developed and used for each of these operations.

At scheduled maintenance or inspection times, voluntary shutdown procedures are to be initiated, usually by first venting all process gases to a flare stack, purging the system twice with steam, and allowing the system to cool down. Voluntary shutdown is

D № 08451

AREA: ______ DATE: ______ TIME: ______ ISSUED TO: ______

EQUIPMENT No.: ______ WORK TO BE DONE: ______

Precautions taken before Permit issued:

| N.B.: Check X in square which applies | Yes | No | n/a |
|---|---|---|---|
| Pressure Released | | | |
| *All Valves Closed/Locked | | | |
| All Valves Tagged | | | |
| Equipment Drained | | | |
| *All Pipes Disconnected/Blanked | | | |
| *Air/Steam/Water/Nitrogen Connected | | | |
| *Purged with Air/Steam/Water/Nitrogen | | | |
| Ventilated | | | |
| Atmosphere Found Gas Free | | | |
| Dangerous Materials Removed | | | |
| Sewer Protected | | | |
| *Starters Locked/Tagged Electrically Isolated: Defect Report No. | | | |
| Driving Belts Removed | | | |
| Temperature Suitable | | | |

Following Pipelines Blanked ______

Other Precautions Taken: ______

Always make initial opening of any equipment as though it were under pressure.

*Delete alternative items not applicable.

Precautions to be taken whilst work is in progress:

| N.B.: Check X in square which applies | Yes | No | n/a |
|---|---|---|---|
| Have Air Masks Available | | | |
| Wear Air Masks | | | |
| Wear Safety Belt | | | |
| Keep Air Flow Through Vessel | | | |
| *Have Air/Water/Steam/Foam Hoses Ready | | | |
| Have Person on Standby | | | |
| Use Spark Proof Tools | | | |
| *Wear Face Shield/Goggles/P V C Hood | | | |
| *Wear Gloves: P V C./Other | | | |
| Wear Acid Resisting Suit | | | |

Other Protective Clothing to be Worn ______

*Explosive/Toxic Gas Test for ______

to be taken every ______ Hours: ______

at the following points ______

Results of Tests are to be recorded on the back of the Control Room copy of this permit.

Other Precautions: ______

I personally certify that the equipment on which work is to be done has been examined and that the work may proceed under the conditions stated herein and on the reverse of this form.

______
Signature of authorised official

I accept the conditions stated on this permit and I certify that all men working on the job will be fully informed of the conditions and precautions to be taken

Signature(s) of Relief Artisan(s)

______ Signature of area engineering official

______ Signature of "outside" official

Permit withdrawn at ______ on ______ for the following reasons: ______

______
Signature

| Trade or Department | Sign on | Sign off |
|---|---|---|
| Electrical | | |
| Instruments | | |
| Fitters | | |
| Welders | | |
| Riggers | | |
| Isolators | | |
| Painters | | |
| Scaffold builders | | |
| Carpenters | | |
| Bricklayers | | |
| Ganger | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Having ascertained that all departments or trades who signed on, have signed off on completion of their tasks, I clear this equipment for operation.

DATE ______ TIME ______ SIGNATURE: ______
Area Engineering official

Figure VI-1

Sample Permit to Do Hot Work, Weld or Burn

Adapted from Reference 12

**CONTINUATION CERTIFICATE**

| Date | Time | Outgoing Production Foreman | Incoming Production Foreman | Authorised Official |
|---|---|---|---|---|
| | 15h00 | | | |
| | 23h00 | | | |
| | 07h00 | | | |
| | 15h00 | | | |
| | 23h00 | | | |
| | 07h00 | | | |
| | 15h00 | | | |
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| | 23h00 | | | |
| | 07h00 | | | |
| | 15h00 | | | |
| | 23h00 | | | |
| | 07h00 | | | |

**GAS TESTS**

| DATE | TIME | LOCATION | TYPE OF TEST | RESULT | SIGNATURE |
|---|---|---|---|---|---|
| | | | | | TESTED BY: |
| | | | | | |
| | | | | | |
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**GENERAL INSTRUCTIONS:**

1. The conditions governing the issue and validity of this permit are described in Instruction No. [illegible], and any amendments thereof.
2. Work must cease and men must be withdrawn if any gas test is beyond the permissible limit.
3. Work must cease on the instructions of any person, pending confirmation by the Production Foreman or more senior official.
4. A ball-point or indelible pencil must be used to fill in the permit. The issuer must ensure that both copies are clearly legible.

Figure VI-2

Sample Safe Work Permit

Adapted from Reference 12

essentially a safe procedure, the principal safety hazard being incomplete purging of process gas before the flanges are "cracked." This hazard can be avoided by using two complete purges before cooldown, and by avoiding, in the original design, S-bends and blind piping, which are difficult to purge.

Comprehensive lock-out and tag-out procedures are essential. The principal single hazard that is characteristic of large multitrain high-BTU coal gasification plants is that individual process units (eg, gasifiers) are directly linked together and to a common utility main. In order to isolate one unit for maintenance, each of the many connections with other units and utilities must be blanked off. Failure to blank off even one of these points effectively may result in hazardous conditions in and around the unit [12].

To prevent asphyxiation of workers in enclosed areas, it is recommended that, wherever possible, steam be used for purging lines and vessels. Steam has very good warning properties (eg, visibility of condensate, increase in temperature), whereas carbon dioxide and nitrogen have none. Also, steam tends to be replaced by air after condensation. In addition, low-pressure steam probably will be readily available.

It must be emphasized that frequent air quality testings, both for the presence of carbon monoxide and for the presence of adequate oxygen, is required during vessel entry, since carbon monoxide and other gases adsorbed onto metal and refractory surfaces can be gradually released over a period of time. In addition to monitoring for carbon monoxide, at one plant a portable monitor is used to test for oxygen concentration before workers are allowed to enter a vessel [12]. At another plant, a portable oxygen detector equipped with an alarm remains in the vessel until the required maintenance work is completed [37]. Such continuous monitoring is recommended.

Employees entering confined spaces should wear suitable harnesses with lifelines tended by an employee outside the confined space who is also equipped with a self-contained breathing apparatus that operates in the pressure-demand mode (positive pressure) and has a full facepiece. The two workers should be in constant communication by some appropriate means and should be under the surveillance of a third person equipped to take appropriate rescue action if necessary [64].

Double-block-and-bleed connections, or the equivalent, are essential on both sides of all process equipment to which access is needed [79]. Spectacle-type blanks or spool pieces are effective in insuring complete isolation before a line is opened and the vessel entered [9]. Furthermore, all residual liquid in isolated sections of piping should be drained through closed systems and not directly to the workplace. Lines containing hazardous gases should be thoroughly purged (also through closed systems).

In high-pressure systems, leaks are major safety considerations in starting up the plant. 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, with particular attention to areas that have recently undergone maintenance or replacement. If no significant leaks are found, the system should be slowly brought up to operating pressure and temperature. The expansion of equipment at high temperature often serves to "tighten up" any pinpoint leaks. If leaks are found, appropriate maintenance should be performed.

Spills and leaks in process areas where toxic liquids are produced (eg, quenching, gas cooling, gas purification, gas-liquor separation, and Phenosolvan) must be cleaned up immediately, and employees engaged in cleanup must wear adequate personal protective clothing and NIOSH- or MSHA-approved respirators. The cleanup operation should be performed and directly supervised by employees instructed and trained in safe decontamination and disposal procedures.

When a significant leak or spill has been located, it must be contained as quickly as possible to minimize the area of contamination. Correction may be as simple as tightening a pump-seal packing gland or switching to spared equipment, or as drastic as initiating a process shutdown. Next, it is necessary to minimize the dispersion of the contamination by perimeter diking. In the case of small spills, a sorbent material may provide effective containment.

Every process area should have a suitable number of manually activated gas alarms for use during gas leaks. These alarms should serve to supplement any automatic gas monitoring systems. The number and placement of the manually activated alarms would vary in the individual work areas, but in the case of a serious leak a worker should have no difficulty reaching the alarm quickly and safely.

Process gas leaks due to the "freezing" of valves by intense process heat can be hazardous. Operators should first attempt to close manual backup valves upstream of the leak. If backup equipment also fails, operators should activate the alarm to initiate emergency shutdown procedures and should leave the area immediately. Emergency crews dressed in proper clothing should be dispatched to the area to begin wetting down structures or discharged solids [88].

Dried tar is difficult to remove from any surface, particularly from the inside of process vessels. Manual scraping and chipping, together with the use of chlorinated hydrocarbon solvents or commercial cleansers, are common methods of cleanup.

Contact of tars with the skin or eyes must be avoided. Where organic solvents are used for this purpose, special care is necessary to prevent employee exposures to solvent vapors. Cleaning solvents should be selected on the basis of low toxicity as well as effectiveness. Approved respirators should be worn while using such solvents. Steam stripping is also commonly used [12] and is effective, but it can cause significant inhalation exposures to airborne particulates, ie, lower-boiling-point residues may vaporize and high-boiling-point material may become entrained in induced air currents. Generally, steam stripping is not recommended because of the potential for the generation of airborne contaminants, but there may be instances (eg, small, confined surfaces) where it must be used. If steam stripping is to be used, it is recommended that NIOSH-approved supplied-air respirators be worn by all employees in the area and in adjacent areas.

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

Hand tools and portable equipment frequently become contaminated and present an exposure hazard to employees who use them. Facilities with adequate ventilation should be provided for cleaning tools and equipment. Effective methods include vapor degreasing and ultrasonic cleaning. Before tools or equipment are returned to service, they should be examined in an ultraviolet darkbox for residual contamination. An ultraviolet scan of the affected areas after decontamination could be used to determine whether additional cleaning is necessary [48].

Process samples, contaminated tools, and equipment being moved out of process areas or going to repair shops should be identified with brightly colored tags [89] to warn employees that a potential hazard exists. Process equipment or areas containing tar, tar oil, or other hazardous materials should be identified by a brightly colored label, specific to the hazard.

Certain hazards are unique to specific gasification processes or unit operations within the process. One example is the potential formation of nickel carbonyl in the methanation units. The probability of this occurrence during steady-state operation of this unit is minimal so long as carbon monoxide does not contact the nickel catalyst at temperatures below 260 C (500 F), ie, lower temperatures should not occur during steady-state operation. To prevent the formation of nickel carbonyl while the methanation unit is being shut down, the partial pressure of the carbon monoxide in the gas stream must be kept low by means such as a hydrogen purge followed by a nitrogen purge. During start-up, this sequence should be reversed until the temperature exceeds 260 C (500 F).

Use of proper personal protective equipment and practice of good personal hygiene are particularly important for employees exposed to tar or tar oil. Employers should provide clothing that protects employees from the hazardous exposures anticipated in carrying out their duties. One effective garment is a jumpsuit type of cotton coverall with a fairly close weave designed to retard the penetration of contaminants yet permit the escape of body heat. The coveralls should be white or light in color so that contamination will be readily visible. Single-use disposable coveralls were tried in a low-BTU coal gasification plant [87], but they were found to be subject to tearing, provided no ventilation, were bulky, and were not well accepted by the employees. Another company reported favorable results with nylon coveralls [90]. In addition to being easily cleaned, these coveralls are reported to be heat resistant and capable of providing satisfactory protection against heat stress during emergency evacuation in the case of fire.

There is evidence that the type of clothing worn underneath the coveralls is very important to the reduction of skin contamination. In an experiment undertaken in 1957 at a coal hydrogenation pilot plant, it was observed that "pajamas," buttoned at the neck and with close-fitting arm and leg cuffs, worn under typical work clothes, were effective [32]. Apparently they prevented contaminants absorbed by the outer clothing from continually coming into contact with the skin. They also provided an additional barrier to vapors and aerosols. It probably would be beneficial if such clothing were worn under the coveralls. However, particularly in hot climates, this may contribute to heat stress, a hazard potentially more significant than the hazards avoided by the added skin protection.

It would be prudent to conduct laboratory tests with several types of protective clothing and fabrics prior to selecting and purchasing a large number of any one type. A decision should be made to determine the imperviousness of the exposed material by fluorescence testing of inner fabric surfaces.

Gloves are usually worn at coal gasification plants during cold weather, when heavy equipment is handled, or 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 absorbent materials should not be used because, once contaminated, they will remain a constant source of skin contamination until laundered. The ideal glove would be impervious to the absorption or passage of process residue and capable of withstanding daily laundering.

Outer clothing for use during cold or inclement weather must be selected carefully to insure that it provides adequate protection and can be laundered or drycleaned to eliminate contamination by process materials.

There should not be large quantities of liquid residue from the gasification processes on the floors, so that regular steel-toed work shoes should provide adequate protection. However, if problems involving footwear contamination do develop, loose, impervious overshoes should be considered. Rubber-soled overshoes are not recommended because the rubber may swell in contact with process oils.

Requirements for other types of protective clothing or devices should be based on the potential exposure as described in the safe work permit, eg, leather gloves and leather hoods with face shields for hot work, acid-resistant suits for use while handling acid.

Experience indicates that an effective method for removing coal-derived contamination from work clothes is drycleaning, followed by washing with soap or detergent and water [27,91,92].

Commercial drycleaning of gloves, socks, special clothing and coveralls of all workers exposed to tar and tar oil is employed by one company engaged in pilot-plant research [87]. The commercial drycleaning establishment receives the contaminated clothing in sealed plastic bags and is warned of the attendant hazard potential. Employees' personal clothing that has become contaminated is treated similarly.

The preceding discussion of protective clothing is pertinent only to gasification processes that produce tar and tar oil. General protective clothing requirements for workers in other plants will vary with the unit process or the job category.

If significant contamination of either exposed skin surfaces or outer clothing occurs, a prompt shower and change of clothing should be required. Because of the importance of this protective measure, supervisory employees must be responsible for insuring strict compliance with this requirement. Employees exposed to tar and tar oils should be required to shower at the end of each shift or at any time they become noticeably contaminated with tar or tar oil.

To promote good personal hygiene practices, to encourage adherence to the daily shower requirement, and to segregate contaminated clothing from street clothing, a double locker room separated partially by a shower facility and partially by one-way door(s) should be installed in such a way that passage from the "clean" to the "dirty" sides can occur only through the one-way door(s), while passage from the "dirty" to the "clean" sides can be accomplished only through the shower facility.

Storage space is necessary on the contaminated side to allow storage of work boots, hardhats, and other safety equipment. Soiled clothing removed after work should be segregated so that outer garments are not mixed with personal clothing that comes into direct contact with the skin. The indiscriminate collection of all clothing may cause the spreading of contamination from overalls, for example, to undergarments. Clothing so badly contaminated that it cannot be effectively laundered should be totally segregated from all other clothing and incinerated. A bin or other container with a tightly fitting lid should be available for the disposal of such clothing.

Many low-BTU gasification plants will be adjuncts to larger facilities and so small that probably only one or two workers may be potentially exposed to contaminants, and then only for several hours per shift. The construction of a double shower room for use by only one or two employees is probably not warranted. One company has reported the use of a specially designed shower trailer to serve the same purpose as the double shower [87]. If such a facility is not used, the minimum provision should be separate areas for clean and "dirty" work clothes for exposed employees.

An adequate number of washrooms should be provided throughout plants to encourage their frequent use by workers. In particular, a washroom facility should be located close to lunchrooms so that employees can wash thoroughly before eating. It is very important that lunchrooms remain uncontaminated to minimize the likelihood of ingesting tar or tar oil. It is necessary that the workers remove contaminated gloves, boots, coveralls, and hardhats before entering lunchrooms. Therefore, some type of interim storage facility should be provided.

Regular soap is recommended for use in showering; the use of organic solvents may facilitate the penetration of contaminants into the skin and thus hinder their removal. It is important also that workers thoroughly wash their hair during showers. Lanolin-based or equivalent nonaqueous hand cleansers should be provided in all washrooms in the plant and in the locker facility. All use of sanitary facilities should be preceded by a thorough cleansing of the hands.

Barrier creams have been suggested as an effective means of reducing skin contact with tar and tar oil, facilitating their removal should contamination occur. Proponents state that, if nothing more, barrier creams contribute to personal hygiene because they must be washed off and with them, presumably, contaminated material. It is further claimed that they provide additional protection for areas of the skin normally not covered by protective clothing (neck and face) and act as a sun screen. The major objection to their use is the unwarranted assumption that barrier creams alone provide adequate protection, which may encourage noncompliance with requirements for personal protective equipment and personal hygiene. Furthermore, it has been speculated that certain barrier creams may exacerbate the spread of tar and tar oils. The effectiveness of presently available barrier creams has not been established, and they are not recommended as a method of reducing skin contact with substances encountered in coal gasification plants. Since many questions regarding the use of barrier creams remain unanswered, research on the subject is recommended.

Respirators are to be considered a last-resort method of reducing employee exposure to airborne toxicants. Their use is acceptable only (1) after it is demonstrated that engineering, work practices, and administrative controls are not sufficient; (2) during periods 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. A respiratory protection program meeting the requirements of 29 CFR 1910.134 must be established and enforced. Employees should be instructed in the proper use and leak-testing of respirators assigned to them.

Because of the complexity of potential exposures and the large number of possible toxicants in any given process area, the utility of cartridge or filter respirators will be limited. Any employee assigned to an operation requiring the use of a respirator should be examined to determine whether he is capable of performing the assigned task while using the device. It is the employer's responsibility to inform the employee of the necessity to use a protective device when the air concentration of hazardous substances cannot be kept at or below the permissible exposure limit. Respirators must be cleaned and inspected after each use. Cleanliness of respirators is particularly important because of the hazard associated with dermal exposure to tar and tar oil. Respirators restrict the wearer's field of vision and often his mobility as well. Since this may result in additional safety hazards, safety procedures appropriate to the job must be developed [93].

Supplied-air lines with a sufficient number of hookup locations could be provided in appropriate plant areas. Most plants will have an abundant supply of such air, but it must be cleaned and filtered for this purpose. The umbilicals and air-line masks could be used primarily during maintenance operations or for work in areas suspected of having high concentrations of toxicants.

Fault-tree analysis and failure-mode evaluation have been mentioned in Chapter V in relation to engineering control applications. Such systems safety techniques could be used to identify necessary work practices as well. References for these techniques are presented in Chapter XIV.

## VII. DEVELOPMENT OF STANDARD

### Basis for Previous Standards

A search was made for occupational health standards in those countries that are or have been actively engaged in the gasification of coal, including Great Britain, the Federal Republic of Germany, and the Republic of South Africa. None of these countries had occupational health standards specifically related to the gasification of coal. A state-by-state search in the United States also failed to uncover occupational health standards specifically related to coal gasification, although New Mexico has environmental regulations specific to high-BTU coal gasification.

In 1967, the American Conference of Governmental Industrial Hygienists (ACGIH) adopted a threshold limit value (TLV) of 0.2 mg/cu m for coal tar pitch volatiles (CTPV), described as a "benzene-soluble" fraction, and listed certain carcinogenic components of CTPV. The TLV was established to minimize exposure to the listed substances believed to be carcinogens, specifically, anthracene, benzo(a)pyrene, phenanthrene, acridine, chrysene, and pyrene [VII-5]. It was promulgated as a Federal standard under the Occupational Safety and Health Act of 1970 [49].

In 1973, NIOSH published Criteria for a Recommended Standard...Occupational Exposure to Coke Oven Emissions, recommending work practices to minimize the harmful effects of exposure to coke-oven emissions and the inhalation of CTPV. In 1974, the Occupational Safety and Health Administration (OSHA) established a Standards Advisory Committee on Coke Oven Emissions to study the problem of the exposure of coke-oven workers to CTPV and to prepare recommendations for an effective occupational health standard. In 1975, the Committee recommended a limit of 0.2 microgram/cu m for benzo(a)pyrene (Federal Register, 41:46741, October 22, 1976).

In 1976, OSHA promulgated a Federal standard for coke-oven emissions designed to reduce employee exposure to carcinogenic chemicals [93]. The standard was based on epidemiologic and animal-experimental evidence, indicating that the chemicals present in coke-oven emissions can produce skin, lung, bladder, and kidney cancer in humans and animals [48]. It was concluded that coke-oven emissions induced lung and genitourinary tract cancer in the exposed population. It was also concluded that coal tar products were carcinogenic to animal skin and were related to increased skin cancer morbidity in human populations similar to coke-oven workers. Thus, protective measures designed to reduce employee exposure to coke-oven emissions were deemed to be warranted. A standard for the benzene-soluble fraction of total particulate matter emitted during the destructive distillation or carbonization of coal was established; specific engineering controls and work practices designed to reduce exposure to coke-oven emissions were mandated [49].

In 1977, NIOSH published _Criteria for a Recommended Standard... Occupational Exposure to Coal Tar Products_, including coal tar, coal tar pitch, and creosote [48]. NIOSH concluded that these materials were carcinogenic and could increase the risk of lung and skin cancer in workers. These products often contain identifiable components which by themselves are carcinogenic, such as BaP, benzanthracene, chrysene, and phenanthrene. Other chemicals from coal tar products such as anthracene, carbazole, fluoranthrene, and pyrene may also cause cancer, but their causal relationships have not been adequately documented. The recommended standard included a permissible exposure limit of 0.1 mg/cu m based on the cyclohexane-extractable fraction of the sample (determined as a TWA concentration for up to a 10-hour workshift in a 40-hour workweek), methods for the sampling and analysis of coal tar products, and specific minimum requirements for medical surveillance, labeling and posting, personal protective equipment and clothing, informing employees of hazards, work practices, sanitation, and monitoring and recordkeeping designed to reduce the health and safety risks from exposure to coal tar products [48].

From 1972 to 1977, NIOSH published criteria for recommended standards for occupational exposure to a number of chemical and physical agents that may constitute occupational health hazards in coal gasification plants (see Table III-10).

## Basis for the Recommended Standard

(a) Engineering Controls

Engineering control recommendations are discussed in Chapter V, with emphasis on process areas suspected or known to present potential occupational safety and health hazards. Examples of such areas are given and methods of controlling the hazards are suggested. Recognizing that the engineering design for commercial coal gasification plants is only now in the process of development, the emphasis is on design to prevent employee exposure. Because of the size and complexity of the process and the variable nature of hazardous emissions, unit-process-specific engineering controls are discussed, as well as those of more general applicability.

(b) Permissible Exposure Limits

Coal gasification plants should comply with permissible exposure limits recommended in NIOSH criteria documents which have not been acted upon by OSHA, and to all applicable Federal occupational standards. There are no reports of chronic disease resulting from occupational exposures in commercial coal gasification plants operated in foreign countries, and there is only one set of reports of health problems in a coal liquefaction pilot plant in the United States [26-27,31-32]. Thus, in the absence of data to support the development of permissible exposure limits specific for the environment of coal gasification plants, NIOSH concluded that in addition to compliance with applicable standards and permissible exposure limits, worker protection could best be achieved through adequate engineering controls, work practices, and medical surveillance.

(c) Sampling and Analysis

To determine compliance with recommended permissible exposure limits, NIOSH recommends use of the sampling and analytical methods presented in the criteria documents referenced in Chapter III (see Table III-10).

Guidelines are presented in Chapter IV for an indicator monitoring concept to allow real-time detection of leakage in coal gasification plants. However, before it is adopted as a procedure for compliance with standards, this method should be compared with methods for the detection of specific hazardous compounds in terms of accuracy and sensitivity.

(d) Medical Surveillance

It is recommendeded that a medical surveillance program be instituted for all occupationally exposed employees and that it include preplacement and interim medical histories supplemented with preplacement and periodic examination of the lungs, the upper respiratory tract, and the skin. Pulmonary function tests [FVC and FEV(1) at a minimum] should be performed, and posteroanterior (14 x 17 inch) chest X-ray films should be made to aid in detecting any existing or developing adverse effects on the lungs. Audiometric examinations should be given to all employees who may be exposed to noise. The skin of employees occupationally exposed to tar or tar oil should be routinely examined for any actinic effects or the presence of benign or premalignant lesions. Suspected malignant lesions should be removed or the employee should be referred to a dermatologist for examination and possible removal of the lesion.

Workers frequently exposed to tar or tar oil should be examined at least annually to permit early detection of adverse effects on the respiratory organs and of sensitization to these materials. In the case of workers potentially exposed to high concentrations of particulate matter, special attention should be given to the oral mucosa. A complete physical examination following the protocol of periodic examinations should be performed when workers terminate employment, if a complete examination has not been performed in the preceding year.

(e) Personal Protective Equipment and Clothing

Employers should provide clean work clothing, workshoes or shoe coverings, gloves, and protective equipment in certain plant areas, as described in Chapter VI.

(f) Informing Employees of Hazards

At the beginning of employment, all employees should be informed of the known occupational exposure hazards associated with coal gasification plants. Signs warning of potentially hazardous exposures must be posted in any work area with a potential for occupational exposure to toxic substances and hazardous conditions. The employer should develop and implement a continuing education program to insure that all employees have current knowledge of job hazards, signs and symptoms of overexposure, proper maintenance and emergency procedures, proper use of protective clothing and equipment, the advantages of good personal hygiene, and of participation in the medical surveillance program.

(g) Work Practices

Work practices are discussed in Chapter VI. They are directed to the prevention of hazardous exposures, fire, and explosion.

(h) Monitoring and Recordkeeping Requirements

Continuous monitors for carbon monoxide or other indicator substances should be used as described in Chapter IV. Performance criteria should be established to facilitate evaluation of progress toward protection objectives. The indicator monitoring concept, coupled with selected sampling and analysis for other toxicants, provides a reasonable vehicle for control performance assessment. The procedures are designed to enable rapid corrective action if a high carbon monoxide concentration is detected. The source of the leak must be found, generally by using a portable air sampler to trace the gas back to its source. Maintenance or other corrective action must then be accomplished. Records of these events, including frequency and severity of leaks by process area, provide an excellent means for comparing performance with objectives and for directing future efforts to problem areas. A further comparison of these records with data from periodic personal monitoring for specific toxicants affords additional performance evaluation.

To insure that sampling and analytical data and medical surveillance information are available for later reference and possible correlation with the health status of employees, employers should keep records of workplace monitoring and employee medical examinations for at least 30 years after the employment of occupationally exposed workers has ended. This will allow an analysis of the efficiency of engineering controls, of exposure potentials, and of the impact of process changes on the concentrations of airborne toxicants and on potential exposure of employees.

# VIII. RESEARCH NEEDS

This chapter summarizes overall research recommendations in the areas of industrial hygiene, process design, process equipment, health effects, monitoring and analytical procedures, and safety.

The CO indicator monitoring concept should be verified at the earliest opportunity. Quantitative sampling and analysis should be accomplished for specific chemical substances in the work environment, and these findings should be compared for accuracy with the expected concentrations calculated in indicator monitoring procedures.

Comprehensive, reliable industrial hygiene evaluations of exposures to hazardous agents in coal gasification plants are needed.

The utility of presently known barrier creams to reduce skin contact with tar and other materials is unsettled, and more information on their effectiveness is needed.

The effectiveness of available cleansing materials for removal of tar from the skin should be investigated. More effective but safe materials are needed.

The effectiveness of ultraviolet (UV) radiation in detecting skin contamination should be thoroughly demonstrated. At the same time the possibility of tissue damage due to the use of UV surveillance should be examined. Alternative procedures for contamination detection should also be investigated.

A study of thermal oxidation processes including incineration should be undertaken to determine and verify the conditions under which complete oxidation of polynuclear aromatic hydrocarbons is effected.

Knowledge of the constituents of the gas stream at each point in the process is crucial in identifying the compounds to which employees may be exposed. The true distribution of trace metals and of sulfur and nitrogen decomposition products, for example, should be determined. At present, estimates of the total distribution are based primarily on calculations. The fate of the radioactive constituents of coal in coal gasification processes should be determined. The effects of shutdown on the deposition of carcinogenic products on surfaces that will be contacted by maintenance and/or production workers should be investigated.

It has generally been assumed that the coked or ashed solids from the reactor are essentially inert. Experimentation is needed to determine the actual hazard classification of these solids.

Under certain operating conditions nickel carbonyl may be formed in the methanator. The maintenance of temperatures above 260 C (500 F) while the synthesis gas is in contact with the catalyst will avoid this problem. However, in the event of an upset in the operating parameters or a "crash shutdown" of part of the process, the operating condition may no longer be safe. There is a need to determine the conditions under which nickel carbonyl is formed in the methanator and the concentrations at which it may occur.

The relative carcinogenicity of polycyclic aromatic hydrocarbons (PAH's) condensed on the exterior surfaces of equipment and structures should be determined by bioassay. PAH's are considered a source of contamination with a potential for skin cancer.

Retrospective morbidity and mortality studies of workers who have left the coal treatment and coal conversion industries should be performed.

Real-time monitoring is desirable, either for all polycyclic aromatic hydrocarbons (PAH's) or for a member of the group such as benzo(a)pyrene, which would serve as an indicator. The present method, measuring the amount of cyclohexane-soluble material in the total particulate matter, is relatively crude and is susceptible to various errors.

The techniques for collecting particulate matter containing PAH compounds should be studied to determine whether there are significant losses of PAH compounds by evaporation.