

## XVI. APPENDIX VIII

### APPLICABLE CODES AND STANDARDS

There are several handbooks, codes, and standards used by various industries that may apply to the design and operation of coal liquefaction plants. Since these publications are generally applicable throughout industry, a detailed presentation of codes and standards relevant to coal liquefaction is beyond the scope of this document. However, a few of the codes and standards that may be applicable are listed here. This list does not in any way imply a comprehensive compilation of codes and standards for coal liquefaction plants.

- (1) American Standard Codes for Pressure Piping, ASA B31.1-1955 and B31.8-1958
- (2) The American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section VIII, "Unfired Pressure Vessels," New York, 1965
- (3) Chemical Plant and Petroleum Refinery Piping, American National Standards Institute (ANSI) B31.3-1976
- (4) National Fire Codes, the National Fire Protection Association Vol 1, "Flammable Liquids"; Vol 2, "Gases"; Vol 3, "Combustible Solids, Dust, and Explosives"; Vol 4, "Building Construction and Facilities"; Vol 5, "Electrical" (the National Electrical Code); Vol 6, "Sprinklers, Fire Pumps, and Water Tanks"; Vol 7 "Alarm and Special Extinguishing Systems"; Vol 8, "Portable and Manual Fire Control Equipment"; Vol 9, "Occupancy Standards and Process Hazards"; and Vol 10, "Transportation"
- (5) Prevention of Dust Explosions in Coal Preparation Plants, ANSI/NFPA No. 653-1959 [ANSI Z12.7]
- (6) Safety Guide for Respiratory Protection Against Coal Mine Dust, ANSI Z88.4-1972
- (7) Liquid Petroleum Transportation Piping Systems, ANSI B31.4-1974, Addenda ANSI B31.4a-1975
- (8) Method of Sampling Petroleum and Petroleum Products, ANSI/ASTM D270-65 (1975)/API 2546-1965 [ANSI Z11.33]
- (9) Safety Standard for Liquid-Level Gauges and Indicators for Petroleum Products, ANSI/UL 180-January 1975 [ANSI B158.1]

- (10) Flame Arresters for Use on Vents of Storage Tanks for Petroleum Oil and Gasoline, ANSI/UL525-September 1973 [ANSI Z222.1]
- (11) Flammable and Combustible Liquids Code, ANSI/NFPA No. 30-1973 [ANSI Z288.1]
- (12) Safety Standard for Pipe Connectors for Flammable Liquids and LP-Gas, ANSI/UL567-August 1972 [ANSI B148.1]
- (13) Gaseous Hydrogen Systems at Consumer Sites, ANSI/NFPA No. 50A-1973 [ANSI Z292.2]
- (14) Liquefied Hydrogen Systems, ANSI/NFPA No. 50B-1973 [ANSI Z292.3]

XVII. APPENDIX IX

ONGOING NIOSH CONTRACTS RELATED TO COAL LIQUEFACTION

ISSUING OFFICE: National Institute for Occupational  
Safety and Health  
Procurement and Grants Management Branch  
5600 Fishers Lane, Room 8-29  
Rockville, Maryland 20857

CONTRACT NUMBER: 210-78-0040

Contract Title: Industrial Hygiene Characterization of  
Coal Gasification Plants

Contract Period: July 18, 1978 to July 17, 1980

Contractor: Enviro Control, Inc.  
One Central Plaza  
11300 Rockville Pike  
Rockville, Maryland 20852

Sponsor: Division of Respiratory Disease Studies

Contract Objective: Perform comprehensive research for industrial hygiene characterization of worker environments, including the development of a catalog of worker exposure through estimations from area sampling and time-motion studies, or through personal sampling in two coal gasification plants; determine the composition of process streams, product and byproduct streams, effluents, and fugitive emissions; identify potential exposure locations, such as waste removal, spent catalyst handling, and other transfer points, and determine whether carcinogens are being concentrated in any process area; conduct a thorough technical characterization of coal gasification on a unit process basis as an integral portion of the overall characterization study; and, based on the technical and industrial hygiene findings, make specific recommendations identifying areas where control technology assessment studies are necessary.

CONTRACT NUMBER: 210-78-0082

Contract Title: Industrial Hygiene Characterization  
of Petroleum Refineries

Contract Period: September 28, 1978 to May 12, 1979

Contractor: Enviro Control, Inc.  
One Central Plaza  
11300 Rockville Pike  
Rockville, Maryland 20852

Sponsor: Division of Surveillance Hazard  
Evaluations and Field Studies

Contract Objective: Perform an in-depth industrial hygiene characterization  
of worker environments in nine selected petroleum refin-  
eries, at selected unit operations, and/or within  
selected job classifications.

CONTRACT NUMBER: 210-78-0084

Contract Title: Control Technology Assessment for the Coal  
Gasification and Liquefaction Processes

Contract Period: September 27, 1978 to December 26, 1980

Contractor: Enviro Control, Inc.  
One Central Plaza  
11300 Rockville Pike  
Rockville, Maryland 20852

Sponsor: Division of Physical Sciences and Engineering

Contract Objective: Conduct a study of the control technology available to  
prevent occupational exposure to hazardous agents in coal  
conversion plants. Where possible, the study will be  
performed on a unit operations basis and will include  
consideration of existing gasification and liquefaction  
pilot plants, existing or planned demonstration and com-  
mercial plants, and similar industrial processes such as  
coke ovens or petroleum refining, where appropriate.

CONTRACT NUMBER: 210-78-0085

Contract Title: Evaluation of Respiratory Protection in  
Coal Preparation Plants

Contract Period: September 29, 1978 to September 28, 1979

Contractor: Enviro Control, Inc.  
One Central Plaza  
11300 Rockville Pike  
Rockville, Maryland 20852

Sponsor: Division of Physical Science and Engineering

Contract Objective: Perform an evaluation of coal mine surface operations to determine the nature of respirable dust and chemical vapor hazards and the use and effectiveness of respirator protective equipment provided to workers against hazardous atmospheres occurring in and around coal mining surface operations such as coal preparation plants, drilling, augering, loading, transporting, and dumping.

CONTRACT NUMBER: 210-78-0101

Contract Title: Study of Coal Liquefaction Processes

Contract Period: February 23, 1971 to February 22, 1980

Contractor: Enviro Control, Inc.  
One Central Plaza  
11300 Rockville Pike  
Rockville, Maryland 20852

Sponsor: Appalachian Laboratory for Occupational  
Safety and Health

Contract Objective: Conduct comprehensive, original research for industrial hygiene characterization of worker environments in four coal liquefaction plants to determine the composition of process streams, product and byproduct streams, effluents, and fugitive emissions. For purposes of this contract, a plant is defined as either a pilot plant, process demonstration unit (PDU), or a commercial plant. This effort will include the identification of potential exposure locations, such as waste removals, spent catalyst handling, and other transfer points, and a

determination of whether carcinogens are being concentrated in some process areas. Based on the technical and industrial hygiene findings, specific recommendations will be made identifying areas where control technology assessment studies are necessary.

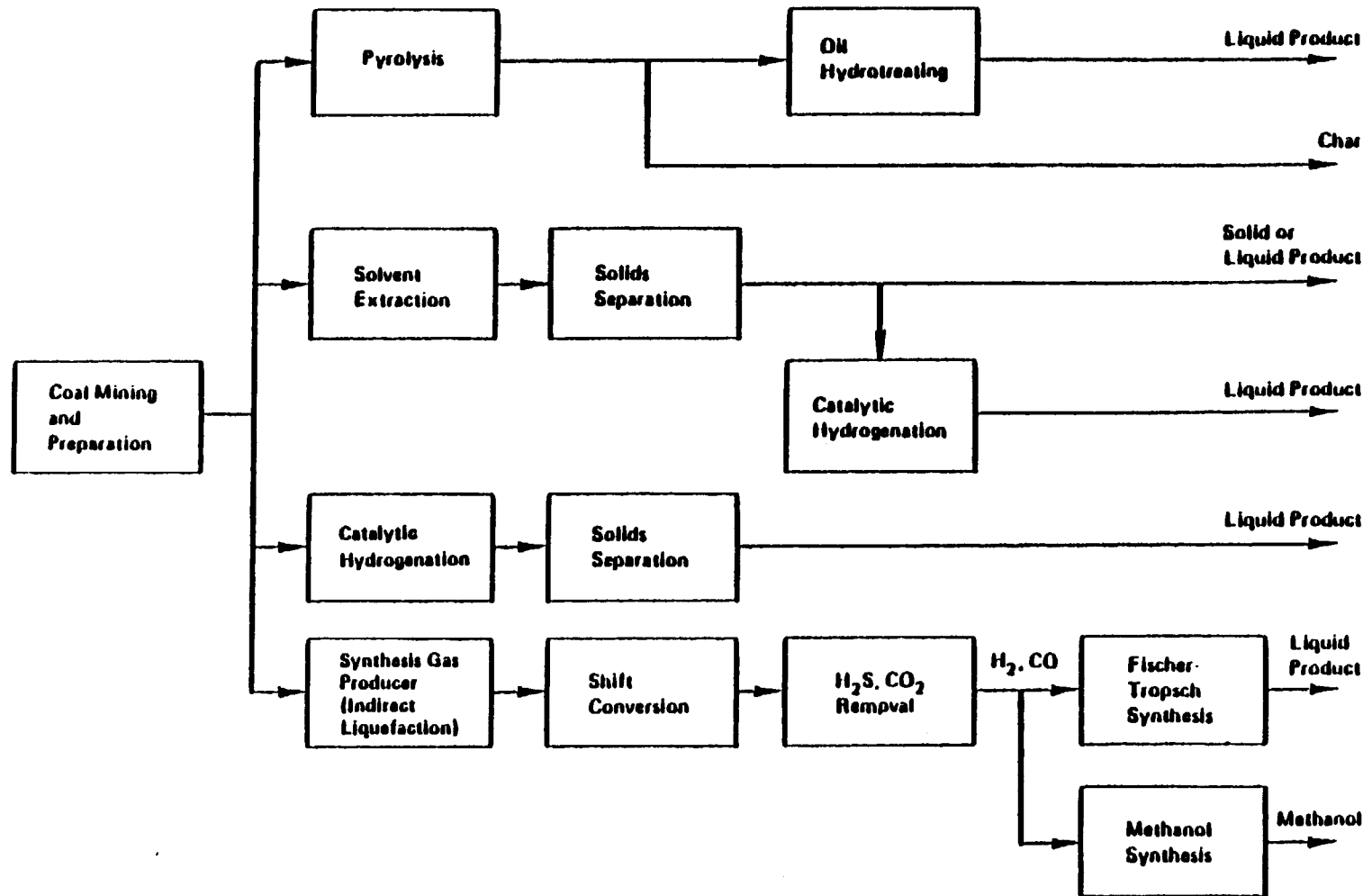
XVIII. TABLE AND FIGURES

TABLE XVIII-1

COAL LIQUEFACTION SEPARATION METHODS

Name	Feed	Separating Agent	Products	Principle of Separation
<b>Equilibration Separation Methods</b>				
Flash expansion	Liquid (slurry)	Pressure reduction	Liquid + vapor	Difference in volatiles (vapor pressure)
Vacuum/flash distillation	Liquid (slurry) and/or vapor	Heat	"	Difference in volatiles
Stripping	Liquid (slurry)	Noncondensate gas	"	"
Solvent de-ashing	Liquid + solid	Solvent	"	Precipitation by increasing particle size (by agglomeration)
Condensation	Liquid and/or vapor	Cooling	"	Difference in volatiles
<b>Mechanical Separation Methods</b>				
Filtration	Liquid + solid	Pressure reduction (energy), filter medium	Liquid + solid	Size of solid greater than pore size of filter medium
Centrifuge (filtration type)	"	Centrifugal force	"	Size of solid greater than pore size of filter medium Density difference
Cyclone	Gas + solid or liquid	Flow inertia	Gas + solid or liquid	Density difference

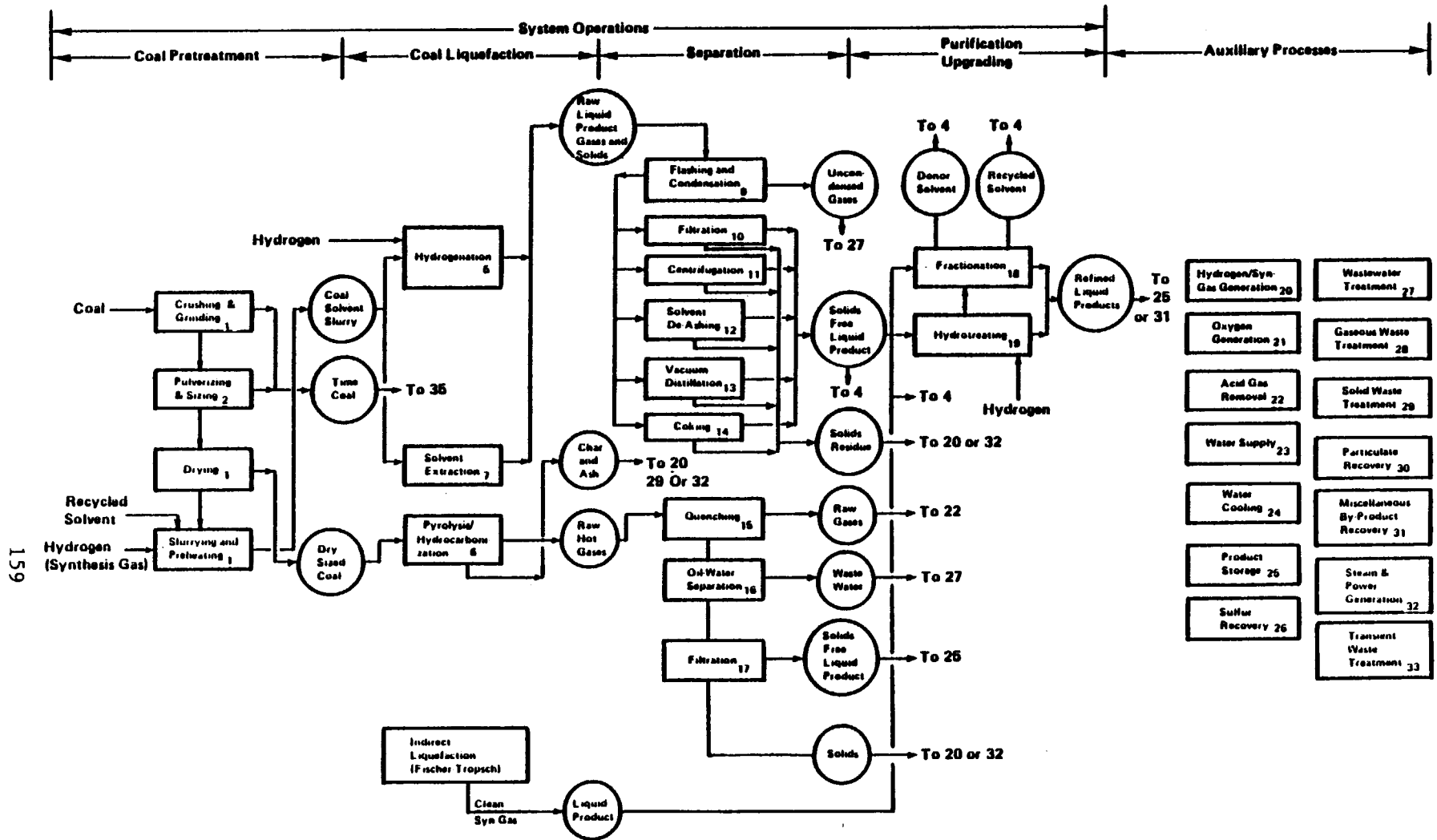
Adapted from reference 31



Adapted from reference 2

FIGURE XVIII-1. COAL LIQUEFACTION ROUTES (ONLY MAJOR PRODUCTS ARE SHOWN)

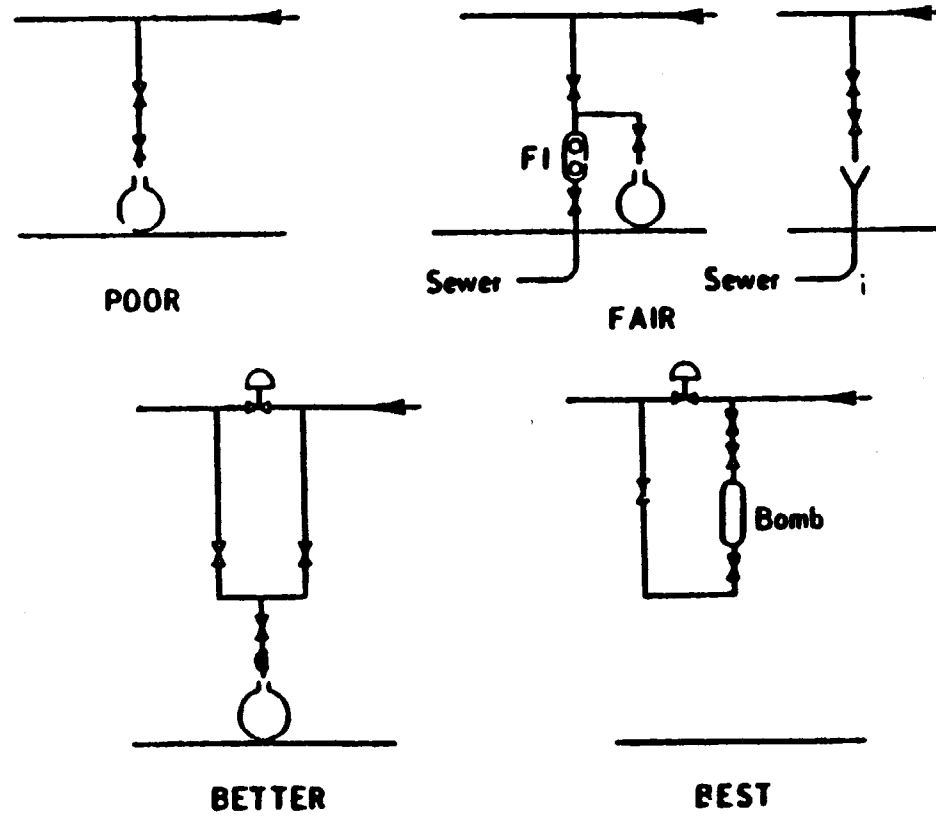




NOTE: The numbers indicate where the process stream goes with in the plant.

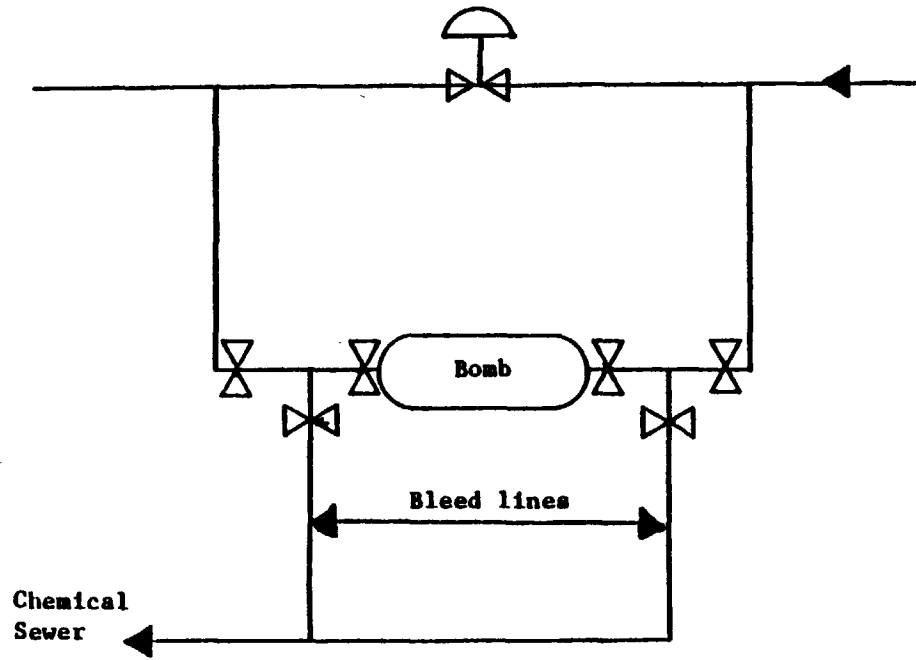
Adapted from reference 31

FIGURE XVIII-2. SCHEMATIC OF GENERAL SYSTEMS USED FOR COAL LIQUEFACTION PROCESSES



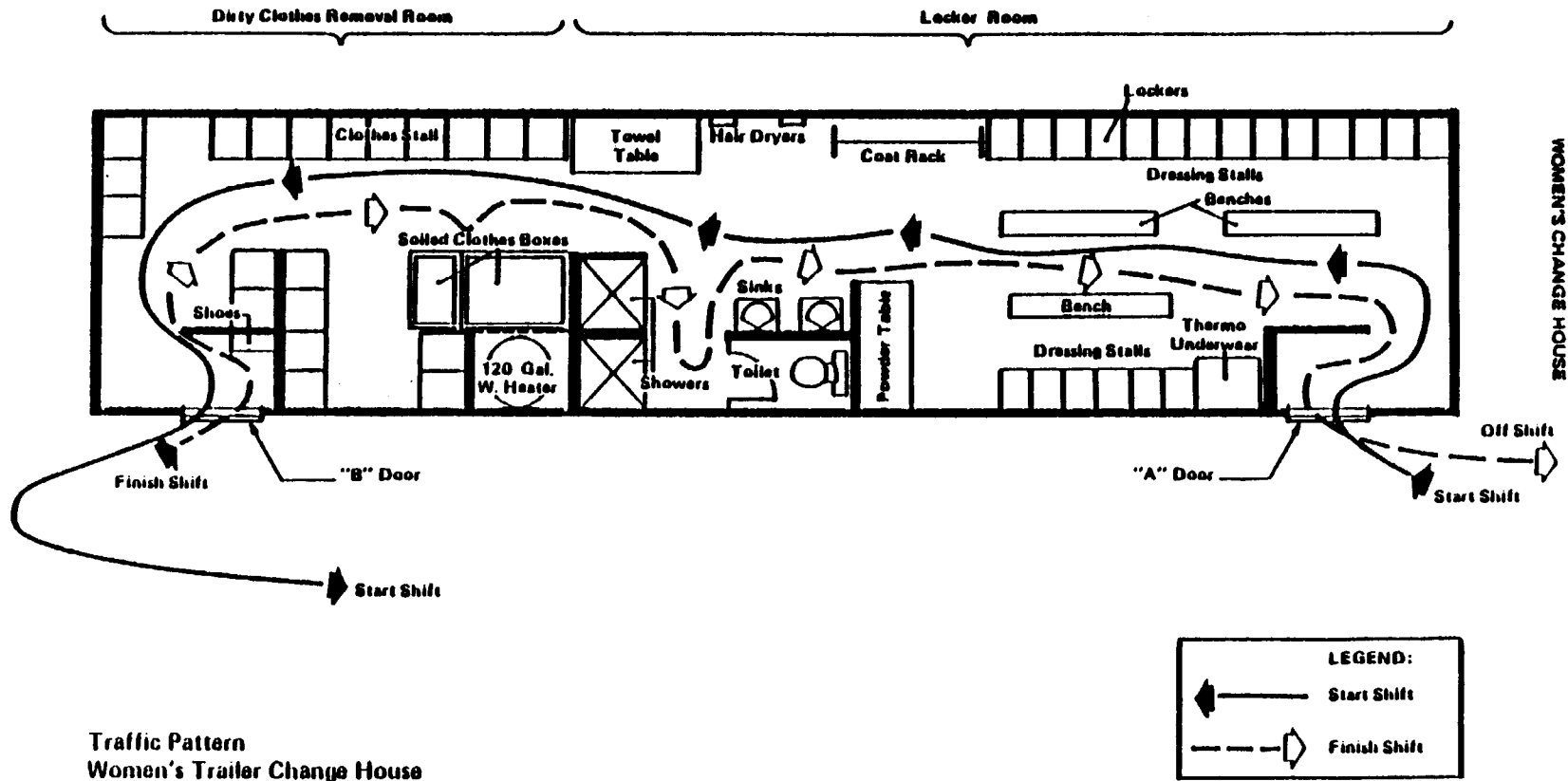
Adapted from reference 107  
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FIGURE XVIII-3. SAMPLING SYSTEMS



Adapted from reference 1

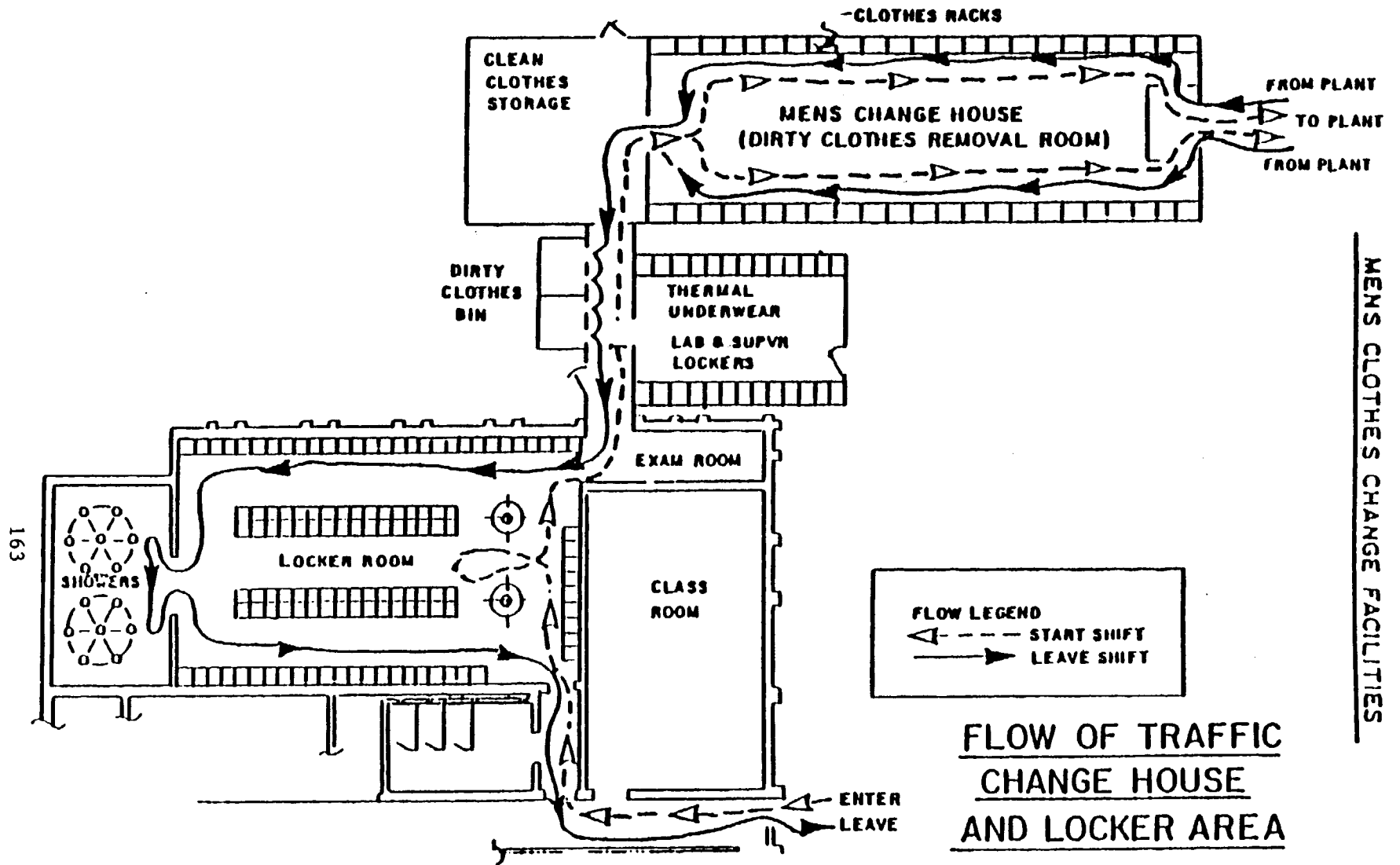
FIGURE XVIII-4. IMPROVED SAMPLING SYSTEM DESIGN



Traffic Pattern  
Women's Trailer Change House

Adapted from reference 116

FIGURE XVIII-5. FLOOR PLAN FOR WOMEN'S CLOTHES CHANGE FACILITIES



MENS CLOTHES CHANGE FACILITIES

Adapted from reference 116

FIGURE XVIII-6. FLOOR PLAN FOR MEN'S CLOTHES CHANGE FACILITIES

## XIX. GLOSSARY

**ACID GAS.** A gas that, when dissolved in an ionizing liquid such as water, produces hydrogen ions. Carbon dioxide, hydrogen sulfide, sulfur dioxide, and various nitrogen oxides are typical acid gases produced in coal gasification.

**ANTHRACITE.** A "hard" coal containing 86-98% fixed carbon and small percentages of volatile material and ash.

**ASH.** Theoretically, the inorganic salts contained in coal; practically, the noncombustible residue from the combustion of dried coal.

**ASPHYXIAN.** A substance that causes unconsciousness or death due to lack of oxygen.

**BENCH-SCALE UNIT.** A small-scale laboratory unit for testing process concepts and operating parameters as a first step in the evaluation of a process.

**BITUMINOUS COAL.** A broad class of coals containing 46-86% fixed carbon and 20-40% volatile matter.

**BLOW DOWN.** Periodic or continuous removal of water containing suspended solids and dissolved matter from a boiler or cooling tower to prevent accumulation of solids.

**BTU.** British thermal unit, or the quantity of energy required to raise the temperature of 1 lb (.454 kg) of water 1°F (.556°C).

**BTX.** Benzene, toluene, xylene; aromatic hydrocarbons.

**CAKING.** The softening and agglomerating of coal as a result of heat.

**CARBONIZATION.** Destructive heating of carbonaceous substances that produces a solid porous residue, or coke, and a number of volatile products. For coal, there are two principal classes of carbonization: high-temperature coking (about 900°C) and low-temperature carbonization (about 700°C).

**CHAR.** The solid residue remaining after the removal of moisture and volatile matter from coal.

**CLAUS PROCESS.** An industrial method of obtaining elemental sulfur through the partial oxidation of gaseous hydrogen sulfide in air, followed by catalytic conversion to molten sulfur.

**COAL.** A readily combustible rock containing >50-weight % and 70-volume % of carbonaceous material and inherent moisture, respectively, formed from compaction and induration of variously altered plant remains.

**COKE.** Porous residue consisting of carbon and mineral ash formed when bituminous coal is heated in a limited air supply or in the absence of air. Coke may also be formed by thermal decomposition of petroleum residues.

**COKING.** Process whereby the coal solution changes to coke.

**CRACKING.** The partial decomposition of high-molecular-weight organic compounds into lower-molecular-weight compounds, generally as a result of high temperatures.

**DEVOLATILIZATION.** The removal of a portion of the volatile matter from medium- and high-volatile coals.

**DISSOLUTION.** The taking up of a substance by a liquid, forming a homogeneous solution.

**DOG.** Any of various, usually simple, mechanical devices for holding, gripping, or fastening.

**EBULLATED BED.** A condition in which gas containing a relatively small proportion of suspended solids bubbles through a higher-density fluidized phase so that the system takes on the appearance of a boiling liquid.

**ECONOMIZER.** Heat-exchanging mechanism for recovering heat from flue gases.

**ELUTRIATION.** The preferential removal of the small constituents of a mixture of solid particles by a stream of high-velocity gas.

**ENTRAIN.** To draw in and transport as solid particles or gas by the flow of a fluid.

**FAULT-TREE ANALYSIS.** An all-inclusive, versatile, mathematic tool for analyzing complex systems. An undesired event is established at the top of a "tree." System faults or subsequent component failures that could cause or contribute to the top event are identified on branches of the tree, working downward.

**FINES.** In general, the smallest particle of coal or mineral in any classification, process, or sample of material; especially those that are elutriated from the main body of material in the process.

**FIXED BED.** A bed in which the individual particles or granules of a solid are motionless (vs a moving bed) and supported by contact with each other.

**FLASH CARBONIZATION.** A carbonization process characterized by short residence times of coal in the reactor to optimize tar yields.

**FLASH DISTILLATION (FLASHING).** A continuous equilibrium vaporization in which all the vapor formed remains in contact with the residual liquid during the vaporization process. It is usually accomplished by the sudden reduction of pressure in a hot liquid.

**FLUE GAS (STACK GAS).** Synonymous terms for the gases resulting from combustion of a fuel.

**FLUIDIZATION (DENSE PHASE).** The turbulent motion of solid particles in a fluid stream; the particles are close enough to interact and give the appearance of a boiling liquid.

**FLUIDIZATION (ENTRAINED).** Gas-solid contacting process in which a bed of finely divided solid particles is lifted and agitated by a rising stream of gas.

**FLUIDIZED BED.** Assemblage of small solid particles maintained in balanced suspension against gravity by the upward motion of a gas.

**GAS LIQUOR (SOUR WATER).** The aqueous acidic streams condensed from coal conversion and processing areas by scrubbing and cooling the crude gas stream.

**GASIFIER.** A vessel in which gasification occurs, often using fluidized-bed, fixed-bed, or entrained-bed units.

**HYDROBLASTING.** A method of dislodging solids using a low-volume, high-pressure (10,000 psi or 70 MPa), high-velocity stream of water.

**HYDROCLONE.** A cyclone extractor that removes suspended solids from a flowing liquid by means of the centrifugal forces that exist when the liquid flows through a tight conic vortex.

**HYDROCRACKING.** The combination of cracking and hydrogenation of organic compounds.

**HYDROGENATION.** Chemical process involving the addition of gaseous hydrogen to a substance in the presence of a catalyst under high temperatures and pressures.



**HYDROGEN DONOR SOLVENT.** Solvent, such as anthracene oil, tetralin (tetrahydronaphthalene), or decalin, that transfers hydrogen to coal constituents causing depolymerization and consequent conversion to lower-boiling liquid products, which are then dissolved by the solvent.

**LIGNITE.** Brownish-black coal containing 65-72% carbon on a mineral-matter-free basis, with a rank between peat and subbituminous coal.

**LIQUEFACTION.** Conversion of a solid to a liquid; with coal, this appears to involve the thermal fracture of carbon-carbon and carbon-oxygen bonds, forming free radicals. Adding hydrogen to these radicals yields low-molecular-weight gaseous and condensed aromatic liquids.

**LOCKHOPPER.** A mechanical device that permits the introduction of a solid into an environment at different pressure.

**METHANATION.** The catalytic combination of carbon monoxide and hydrogen to produce methane and water.

**MOVING BED.** A body of solids in which the particles or granules of a solid remain in mutual contact, but in which the entire bed moves (vs a fixed bed) in piston-like fashion with respect to the containing walls.

**PILOT PLANT.** A small-scale industrial process facility operated to test a chemical or other manufacturing process under conditions that yield information about the design and operation of full-scale manufacturing equipment.

**POUR POINT.** The lowest temperature at which a material can be poured.

**PRILLING TOWER.** A tower that produces small solid agglomerates by spraying a liquid solution in the top and blowing air from the bottom.

**PROCESS DEVELOPMENT UNIT.** A system used to study the effects of process variables on performance, between a bench-scale unit and a pilot plant in size.

**PROCESS STREAM.** Any material stream within the coal conversion processing area.

**PRODUCT STREAM.** A stream within a coal conversion plant that contains the material the plant was built to produce.

**PYROLYSIS.** Thermal decomposition of organic compounds in the absence of oxygen.

**QUENCHING.** Cooling by immersion in oil, water bath, or water spray.

**RANK.** Differences in coals due to geologic processes designated as metamorphic, whereby carbonaceous materials change from peat through lignite and bituminous coal to anthracite or even to graphite; the degree of coal metamorphism.

**REGENERANT.** A substance used to restore a material to its original condition after it has undergone chemical modification necessary for industrial purposes.

**SHIFT CONVERSION.** Process for the production of gas with a desired carbon monoxide content from crude gases derived from coal gasification. Carbon monoxide-rich gas is saturated with steam and passed through a catalytic reactor where the carbon monoxide reacts with steam to produce hydrogen and carbon dioxide, the latter being subsequently removed in a scrubber by a suitable sorbent.

**SLAG.** Molten coal ash composed primarily of silica, alumina, and iron, calcium, and magnesium oxides.

**SLUDGE.** A soft mud, slush, or mire, eg, the solid product of a filtration process before drying.

**SLURRY.** A suspension of pulverized solid in a liquid.

**SOUR GAS.** A gas containing acidic substances such as hydrogen sulfide or carbon dioxide.

**SOUR WATER.** See gas liquor.

**SPARED EQUIPMENT.** Standby, parallel equipment that is available for immediate use by switching power or process from on-stream equipment.

**STACK GAS.** See flue gas.

**STUFFING BOX.** A device that prevents leakage from an opening in an enclosed container through which a shaft is inserted.

**SUBBITUMINOUS COAL.** Coal of intermediate rank (between lignite and bituminous); weathering and nonagglomerating coal having calorific values in the range of 8,300-11,000 BTU (8,756,500-11,605,000 J), calculated on a moist, mineral-matter-free basis.

**SWEET GAS.** Gas from which acidic constituents such as hydrogen sulfide have been removed.

**SYNTHETIC NATURAL GAS (SNG).** Substitute for natural gas; a manufactured gaseous fuel, generally produced from naphtha or coal; that contains 95-98% methane and has an energy content of 980-1,035 BTU/ft<sup>3</sup> (36.5-38.6 MJ/m<sup>3</sup>), or about the same as that of natural gas.

**SYNTHESIS GAS.** A mixture of hydrogen and carbon monoxide that can be reacted to yield hydrocarbons.

**SYSTEM.** A collection of unit operations and unit processes that together perform a certain function. For example, the coal handling and preparation system consists of the following unit operations: crusher, pulverizer, and dryer.

**TAR (COAL).** A dark brown or black, viscous, combustible liquor formed by the destructive distillation of coal.

**TAR OIL.** The more volatile portion of the tar, with a specific gravity of approximately 0.9 and a boiling range of approximately 185-300°C, depending on the coal feed and operation conditions. In addition, tar oil floats on the gas liquor.

**TOXICANT.** A substance that injures or kills an organism through chemical or physical action, or by alteration of the organism's environment.

**TRACE ELEMENTS.** A term applied to elements that are present in the earth's crust in concentrations of <0.1% (1,000 ppm). Concentrations are usually somewhat enriched in coal ash. Environmentally hazardous trace elements in coal include antimony, arsenic, beryllium, cadmium, lead, mercury, selenium, and zinc.

**VENTING.** Release to the atmosphere of gases or vapors under pressure.

**UNIT OPERATIONS.** Equipment application resulting in physical changes of the material, eg, pulverizers, crushers, and filters.

**UNIT PROCESSES.** Equipment application resulting in chemical changes or reactions of the material, eg, hydrotreater, gasifier, and pyrolysis reactor.

XX. ACRONYMS

ANSI American National Standards Institute  
API American Petroleum Institute  
ASME American Society of Mechanical Engineers

BOM Bureau of Mines

CBC complete blood count  
CCL catalytic coal liquefaction  
CFFC clean fuel from coal  
CNS central nervous system  
COED char-oil-energy development  
CSF Consol synthetic fuel

DEA diethanolamine  
DMR dry mineral residue  
DMSO dimethyl sulfoxide

ECG electrocardiogram  
EDS Exxon donor-solvent  
ERDA Energy Research and Development Administration

FEV<sub>1</sub> forced expiratory volume in 1 second  
FHP flash hydrolysis process  
FVC forced vital capacity

GC gas chromatography  
GGPT gamma glutamyl transpeptidase

Hb hemoglobin

LC<sub>50</sub> lethal concentration for 50% survival of group  
LD<sub>50</sub> lethal dose for 50% survival of group  
LD lethal dose

MFAO mixed-fraction amine oxidase  
MS mass spectrometry

NFPA National Fire Protection Association  
NIOSH National Institute for Occupational Safety and Health

OCR Office of Coal Research  
ORC Occidental Research Corporation  
ORNL Oak Ridge National Laboratory

PAH polycyclic aromatic hydrocarbon  
PDU process demonstration unit  
PEL permissible exposure limit  
PETC Pittsburgh Energy Technology Center

QA quality assurance

RBC red blood cell  
ROM run-of-mine  
RPE, 0 relative plating efficiency

SASOL South African Coal, Oil, and Gas Corporation, Ltd  
SGE supercritical gas extraction  
SGOT serum glutamic oxaloacetic transaminase  
SGPT serum glutamic pyruvic transaminase  
SHE Syrian hamster embryo  
SRC solvent-refined coal  
SRL solvent-refined lignite

TLC thin-layer chromatography  
TWA time-weighted average

UV ultraviolet

WBC white blood cell

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