SECTION 11

ENVIRONMENTAL FACTORS

Thi. conceptual design is responsive to requirements for control of gaseous, liquid, and solid emissions from the plant units and ancillary facilities. The means by which gas, vapor, liquid, and solids emission control, as well as noise level control have been accomplished are discussed below.

11.1 AIR POLLUTION ABATEMENT

The control of air contaminants released to the environment had a high priority in plant and process design. Applicable standards covering the process operations were used in design and engineering of the process and equipment.

The major air pollution abatement effort is aimed at desulfurizing the gases generated during the coal conversion process to make the fuels produced environmentally acceptable.

11.1.1 GENERATION AND CONTROL OF GASEOUS CONTAMINANTS

The generation and control of gaseous contaminants are outlined in Figure 11-1, which also shows the nature and amount of all streams vented to the air. These consist primarily of inert gases, nitrogen, and carbon dioxide.

Fugitive particulate emissions from coal sizing and handling, and from residual ash disposal are prevented from becoming airborne by maintaining a wet condition when not in a closed system.

The coal grinding and drying unit is the only source of particuate emissions. A baghouse system removes most of the particulates from the vent streams, with emissions to the air (0.030 gr/ft^3 maximum) meeting both the Federal standard for thermal dryer gases (0.031 gr/ft^3) and other standards related to coal gasification plants. The source of heat for the drying process is steam; no combustion gases are generated by the operation..

Ground, dry coal is fed to three reactors: the dissolver and the pyrolyzer, which produce liquid and gaseous fuels, and the fuel gas gasifier, which produces fuel gas used for in-plant needs and for power generation. The char residue from the pyrolyzer is fed to a fourth reactor, the process gasifier, which produces the hydrogen required for coal dissolving.

The output from each of the two gasifiers is raw gas containing hydrogen, carbon monoxide, carbon dioxide, methane, hydrogen sulfide, entrained char, and lesser amounts of ammonia, carbonyl sulfide, and cyanides. At the elevated reactor temperature, any oils or tars formed are expected to crack to

gaseous products. The entrained char is separated by cyclones followed by ionizer-collectors; the particulates collected are returned to the gasifiers, where the carbon fraction can be gasified and the inorganic fraction is removed as slag. Final cooling of the gas streams occurs in a quench pot/condensate separator, which acts also as a water scrubber, removing practically all traces of remaining particulates. The ammonia and part of the hydrogen sulfide and hydrogen cyanide present are removed at the same time. The next treatment step achieves a nearly quantitative removal of acid gases from the gas streams by means of a physical solvent process. On selective regeneration of the solvent, a stream of hydrogen sulfide containing part of the carbon dioxide and a stream of nearly pure carbon dioxide are released. The hydrogen sulfide streams are sent to the sulfur recovery plant where they are oxidized to elemental sulfur; any hydrogen cyanide present is oxidized concurrently. The carbon dioxide streams, containing some carbon monoxide and hydrogen sulfide, are combined with other tail gases from similar units (see below).

The dissolver unit receives a preheated, pressurized slurry of ground coal in coal-derived solvent and hydrogen, and generates two product phases, a gas phase and a slurry phase. The gas phase is cooled and depressurized, then conveyed to an acid gas removal unit, where hydrogen sulfide is removed by reaction with an amine and the traces of carbon dioxide present are removed by reaction with caustic. The acid gas stream obtained on regeneration of the amine is fed to the sulfur recovery plant.
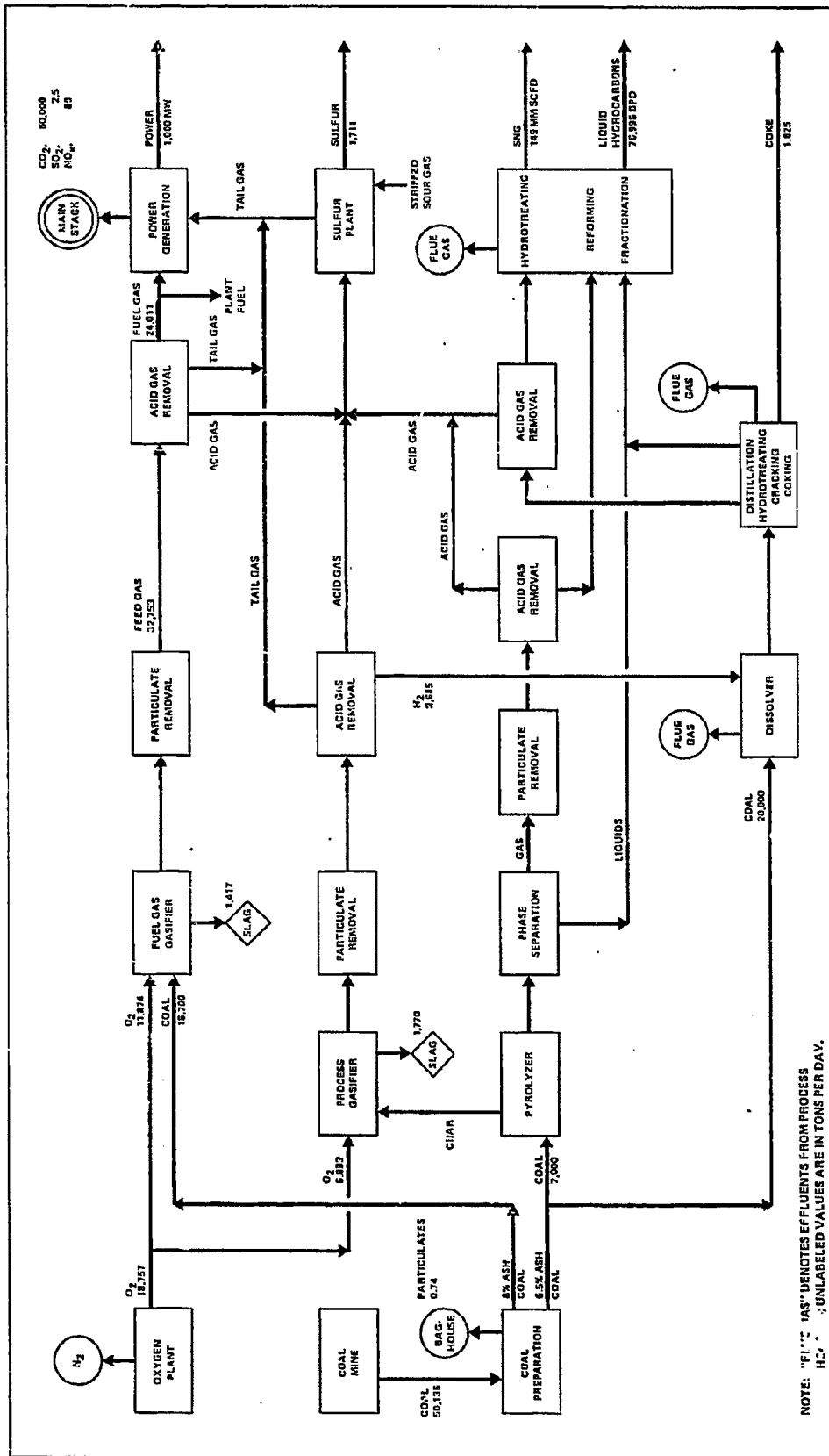
The pyrolyzer receives ground coal and vacuum distillation bottoms from the dissolver and converts them to gaseous and liquid products and char. The gas stream is freed of particulates using the same procedure followed for the gasifiers; it is then conveyed to an acid gas removal unit, operating similarly to the unit described above for the dissolver.

11.1.2 SULFUR RECOVERY PLANT

The sulfur recovery plant receives the hydrogen sulfide streams originating from the four acid gas removal units mentioned above, and from all sour water stripping units; 95% of the sulfur present is oxidized to high purity elemental sulfur, with the remaining 5% converted in a subsequent unit, the tail gas unit. The tail gas treatment involves reduction of all sulfur species to hydrogen sulfide, absorption by an alkaline solution, and oxidation to give high purity sulfur. The final effluent, containing carbon dioxide plus traces of carbon oxysulfide, hydrogen sulfide, and carbon monoxide is combined with the tail gases from the acid gas removal units (see below).

11.1.3 AIR EMISSIONS

Gaseous effluents are emitted into the air from the coal drying plant (particulates); the plant process heaters (consuming approximately one-fifth of the fuel gas produced); the main plant stack (all other effluents combined). The composition of the effluents emitted to the air from the outlets specified is detailed in Table 11-1.

Figure 11-1 - Block Flow Diagram - Air Pollution Abatement

MAIN STACK

POWER GENERATION — POWER 1,000 MW
CO₂: 50,000 SO₂: 2.5 NOₓ: 83

SULFUR PLANT — SULFUR 1,711
STRIPPED SOUR GAS

HYDROTREATING / REFORMING / FRACTIONATION
SNG 149 MMSCFD
LIQUID HYDROCARBONS 76,996 BPD
COKE 1,825

FLUE GAS

ACID GAS REMOVAL
TAIL GAS
FUEL GAS 26,011
PLANT FUEL
TAIL GAS
ACID GAS

ACID GAS REMOVAL

DISTILLATION / HYDROTREATING / CRACKING / COKING
FLUE GAS

PARTICULATE REMOVAL
FEED GAS 32,753

ACID GAS REMOVAL
ACID GAS
TAIL GAS

ACID GAS REMOVAL
H₂ 2,685

DISSOLVER
FLUE GAS
COAL 20,000

FUEL GAS GASIFIER
SLAG 1,417
O₂ 11,974
COAL 18,700

PARTICULATE REMOVAL

PROCESS GASIFIER
SLAG 1,770
O₂ 6,892
CHAR

PYROLYZER
COAL 7,000

PARTICULATE REMOVAL
GAS

PHASE SEPARATION
LIQUIDS

OXYGEN PLANT
N₂
O₂ 18,757

COAL MINE
COAL 50,135

BAG HOUSE
PARTICULATES 0.74
8% ASH COAL
6.5% ASH COAL

COAL PREPARATION

NOTE: "FLUE GAS" DENOTES EFFLUENTS FROM PROCESS
H₂ ... ; UNLABELED VALUES ARE IN TONS PER DAY.

11-3

Table 11-1 - Effluents Emitted to the Air

Outlet	Gaseous Effluent	Amount (TPD)	Concentration
Main Stack	Carbon dioxide	59428	-
	Sulfur dioxide	2.5	3 ppm
	Nitrogen oxides	88.6	139 ppm
Process Heaters	Carbon dioxide	7672	-
	Sulfur dioxide	0.04	0.7 ppm
	Nitrogen oxides	1.4	50 ppm
Coal Drying Plant	Particulates	0.74	$0.03 \ gr/ft^3$

The gas turbines used for power generation and the plant process heaters are fueled by the cleaned medium Btu ($320 \ Btu/ft^3$) fuel gas produced in-plant. On combustion, the very small amount of SO_2 shown in Table 11-1 is generated by oxidation of the trace of hydrogen sulfide present.

The amount of nitrogen oxides generated by the process heaters · is also moderate, because of the medium Btu value of the gas and the flame-cooling effect of the inert gases (carbon dioxide and nitrogen) present. Larger amounts are produced by the gas turbines due to the higher temperatures encountered; nitrogen oxide generation is controlled by injection of steam.

As mentioned above, the tail gases from the acid gas removal units contain traces of carbon monoxide and hydrogen sulfide; the sulfur plant tail gas contains, in addition, traces of carbon oxysulfide. The control treatment contemplated for these combined tail gases (Figure 11-1) involves thermal oxidation to carbon dioxide, sulfur dioxide, and water in .the gas turbine combustors. The tail gases can be either combined with the fuel gas or added to the combustion air. The mass and volumetric compositions of the final effluent emitted are shown in Table 11-1 (main stack).·

11.1.4 COMPLIANCE WITH SOURCE EMISSION STANDARDS

Source Emission Standards for coal conversion plants have not been issued by the Federal Government. Guidelines for hydrocarbon (100 ppm) and sulfur dioxide (250 ppm) have been proposed by EPA for Lurgi coal gasification plants. These guidelines are not applicable to the POGO plant because a different technology is used; they are, however, met by the plant effluents.

Of the states, only New Mexico has issued specific regulations covering coal gasification plants; these regulations can be considered for illustrative purposes only because the POGO plant, as conceived, would be located in the U.S. Eastern Interior (coal) Region. The State of Illinois has

issued standards for petrochemicals; this technology is somewhat related to a Fischer-Tropsch operation. Federal standards for petroleum refinery sulfur recovery plants have been proposed; POGO technology uses similar sulfur recovery procedures. For illustration purposes only, the Federal, Illinois, and New Mexico source emission standards are compared, in Table 11-2, with the emissions from the conceptual POGO coal conversion plant. As shown in the table, all estimated emissions are projected to either meet or be below the standards.

11.1.5 SULFUR BALANCE

The sulfur balance for the conceptual design of a commercial POGO plant is detailed in Table 11-3. More than 99% of the coal sulfur content is recovered as elemental sulfur. The remainder is emitted as sulfur dioxide on oxidation of the traces of reduced sulfur species present in the fuel gas and in the tail gases. The gaseous and liquid fuels produced for sale contain no sulfur.

11.1.6 CARBON DIOXIDE EMISSIONS

It is estimated that significant carbon dioxide emissions (on the order of 67,000 TPD, Table 11-1) would be generated by the POGO commercial plant. It appeared desirable to investigate possible effects of these emissions. Carbon dioxide is not toxic, and the natural background concentration in the atmosphere has been estimated at 300 to 500 ppm.

Global weather modification effects have been attributed to increased carbon dioxide generation by fossil-fuel combustion. A gradual warming trend has been predicted, on the order of 0.5°C in 25 years. However, actual temperature trends have shown a cooling of 0.3°C from 1945 to the present.

On a localized scale, no micrometeorological effects due to increased carbon dioxide have been reported. Emissions from the POGO facility could approximately double the average atmospheric carbon dioxide concentrations to 600 to 1000 ppm in the vicinity of the plant. The lowest concentration at which some physiological effects (dyspnea and headache) have been observed is 30,000 ppm; therefore, no effects are expected at the levels mentioned. However, vegetable life has been reported to benefit from increased atmospheric concentrations of carbon dioxide.

11.2 AQUEOUS EFFLUENTS

The geographic area where the POGO plant, as conceived, would be located, is the U.S. Eastern Interior (coal) Region, where an abundant supply of water is available. Most likely, one of the major rivers in this area would provide the water supply for the plant.

Based on adequate availability of water, the wastewater treatment is a combination of recycling and discharge of aqueous effluents. The most heavily contaminated streams undergo steam distillation; the organic contaminants separated are fed with steam to the process gasifier to achieve their thermal

Table 11-2 – Comparison of Gaseous Emissions From the Conceptual POGO Conversion Plant with Federal, Illinois, and New Mexico Source Emission Standards

Pollutant	Federal Standards, Petroleum Refinery Sulfur Recovery Plant	Illinois Standards, Petrochemical Plant	New Mexico Standards, Coal Gasification Plant	Gaseous Effluents, POGO Plant
Particulate Matter	0.031 gr/ft³ [d]	78 lb/hr	0.03 gr/ft³	0.030 gr/ft³, 62 lb/hr [b]
Sulfur Dioxide	250 ppm [c] 126 ppm [d]	1.2 lb/MM Btu	-	3 ppm, 0.005 lb/MM Btu
Carbon Monoxide	-	200 ppm, 50% excess air	-	Nil
Nitrogen Oxides	139 ppm [d]	0.7 lb/MM Btu	-	139 ppm, 0.18 lb/MM Btu [e]
Organics (methane excluded)	-	100 ppm (CH₄ equivalent)	-	Nil
Total Reduced Sulfur (H₂S + COS + CS₂)	300 ppm [c]	-	100 ppm	Nil
Hydrogen Sulfide	100 ppm [c]	-	10 ppm	Nil
Hydrogen Cyanide	-	-	10 ppm	Nil
Hydrogen Chloride/ Hydrochloric Acid	-	-	5 ppm	Nil
Ammonia	-	-	25 ppm	Nil
Gas Burning Process Boilers, Particulate Matter	-	-	0.03 lb/MM Btu, LHV	Nil
Gas Burning Process Boilers, Sulfur Dioxide	-	-	0.16 lb/MM Btu, LHV	0.001 lb/MM Btu
Total Sulfur	-	-	0.008 lb/MM Btu of feed	0.005 lb/MM Btu

a Standard for coal thermal dryer gases.
b From the coal drying plant.
c Proposed standard, petroleum refinery sulfur recovery plant (41 FR 43866, Oct. 4, 1976).
d Proposed standard, stationary gas turbine (42 FR 53782, Oct. 3, 1977).
e Includes emissions from the gas turbines (0.177 lb/MM Btu) and from the process heaters (0.003 lb/MM Btu).

Table 11-3 - Sulfur Balance

Sulfur Contributions	TPD
Total Input from the typical feed coal	1712.2
Outputs: Recovered as elemental sulfur	1711.0
As sulfur dioxide emissions from combustion of fuel gas	0.1
As sulfur dioxide emissions from thermal oxidation of reduced sulfur species	1.1
	1712.2

destruction. Medium contaminated streams are purified physically and biologically, then are reused for slag quenching. The lightly polluted streams are treated to make them acceptable to the environment, then are discharged to the river.

11.2.1 GENERATION AND TREATMENT OF AQUEOUS CONTAMINANTS

The generation and treatment of aqueous contaminants is outlined in Figure 11-2. Waste water sources are listed on the left hand side of the figure, with the degree of pollution of the waste water streams decreasing from top to bottom. The progressive treatment and disposition of the streams is also shown; approximate flow values of streams withdrawn and returned to the river are reported.

The water supply, provided by a major river, consists of 24,000 gpm of raw water, which, after purification by flocculation and settling, is used for cooling water makeup and, after further sand filtration and deionization, for boiler feedwater makeup. Potable water is expected to be supplied by wells. The water supply from the river is not used for coal sizing and cleaning (a captive system, feeding on a mine-based pond, is used for this unit) or for coal grinding and drying, where no wet systems are employed.

The most highly contaminated stream contains the combined sour water generated as aqueous condensates by the process gasifier, the fuel gas gasifier, and the coal dissolver. Major contaminants present are hydrogen sulfide, ammonium sulfide, phenols, cresols, xylenols, thiocyanates, mercaptans, and cyanides. Solids (ash and char particles) may also be present. After gravity separation of floating oil, the gaseous contaminants (hydrogen sulfide and ammonia) are removed by steam stripping. Ammonia is separated by contact with an ammonium phosphate/phosphoric acid solution, regenerated on heating, and purified to anhydrous ammonia; hydrogen sulfide is conveyed to the sulfur plant for conversion to elemental sulfur; under the acidic conditions of the sour water, any cyanides present would be volatile (hydrogen cyanide), and therefore be stripped with the hydrogen sulfide and conveyed to the sulfur plant, there to be destroyed by thermal oxidation. The stripped aqueous stream is conveyed to a high temperature steam drum in the process gasifier unit, where the organic

11-7

contaminants volatilize and are fed with the steam to the gasifier, there to undergo thermal oxidation; the blowdown from the steam drum is vaporized on cooling the product gas prior to shift conversion; any solids present are removed by filters in the condensate return lines.

Oily water streams produced during plant operation or collected as contaminated runoff from process areas are conveyed to a gravity separator. The water phase is further purified in an oily water pond, with the effluent used for slag quench. The combined oil fractions are fed to a separator, with the oil phase returned to the fractionation unit for product recovery; the aqueous phase is combined with the effluents from the slag settling basin and the sewage treatment plant and treated in a bio-oxidation pond, which provides fire water; the effluent from the biopond is also used for slag quench.

The cooling tower fulfills cooling requirements for both process and power plants. The cooling tower blowdown stream is the largest stream in volume, and is only lightly contaminated by corrosion inhibitors (zinc salts and inorganic phosphates). This stream is combined with deionizer wastes, containing mainly inorganic salts, and with boiler blowdown, also lightly contaminated by corrosion inhibitors, then, after neutralization, it is treated with lime in a settler-clarifier. The lime sludge, containing most of the zinc and phosphates, is disposed of in a landfill, while the treated stream is returned to the river together with any runoff collected from clean areas. If required by specific site conditions, a final polishing pond may be added for removal of suspended solids from the runoff collected.

11.2.2 COMPLIANCE WITH EFFLUENT STANDARDS

No aqueous effluent standards specifically addressed to coal conversion plants have been issued by the Federal Government or by state legislatures. Standards that are somewhat related to a POGO process are the Federal standards issued for petroleum refining. Average attainable concentrations, which were the basis for such standards, are reported in Table 11-4, together with the corresponding values for the aqueous effluents estimated for the POGO plant. As shown in the table, these values are either the same or lower than the Federal parameters.

The State of Illinois has issued aqueous effluents standards applicable to all sources discharging to the natural waters of the state. These standards are reported in Table 11-5. All POGO plant effluents estimated either meet or are lower than such standards.

11.3 SOLID WASTES

The POGO plant generates two main types of solid waste materials; slag from the coal gasifiers and sludge from various waste water treatment units. Both materials are disposed of using environmentally acceptable procedures.

The mining and coal cleaning and sizing operations generate sizable amounts of solid wastes, which are disposed of at the mine site.

Table 11-4 - Comparison of Aqueous Effluents with
Federal Petroleum Refinery Standards[a]

Parameter	Federal Standards, Petroleum Refinery	Aqueous Effluents, POGO Plant
BOD-5	15	10
COD	100	100
Total organic carbon	33	33
Suspended solids	10	10
Oil and grease	5	5
Phenol	0.1	nil
Ammonia-N	80% removal	nil
Sulfide	0.1	nil
Chromium, tertiary	0.25	nil
Chromium, hexavalent	0.005	nil

[a]Average attainable concentrations from the application of best practi-
able control technology currently available[9].

Table 11-5 - Aqueous Effluent Standards, State of Illinois

Constituent	Maximum Concentration (mg/l)
Arsenic (total)	0.25
Barium (total)	2.0
BOD-5	10.0
Cadmium (total)	0.15
Chromium (total hexavalent)	0.3
Chromium (total trivalent)	1.0
Copper (total)	1.0
Cyanide	0.025
Fluoride (total)	15.0
Iron (total)	2.0
Iron (dissolved)	0.5
Lead (total)	0.1
Manganese (total)	1.0
Mercury (total)	0.0005
Nickel (total)	1.0
Oil (hexane solubles or equivalent)	15.0
pH	range 5-10
Phenols	0.3
Selenium (total)	1.0
Silver	0.1
Zinc (total)	1.0
Total Suspended Solids	12.0

11.3.1 SLAG

The two gasifiers included in the POGO plant design generate 3187 TPD of slag (Figure 11-1). The slag is withdrawn from the bottom of the gasifiers; on quenching with water, it fragments into sand granules. Gases generated on quenching are returned to the gasifier. The slag slurry is conveyed to a settling basin where the solids separate; they are then collected and transported to the mine for burial with the mine spoils. If outlets exist nearby, this material could also be utilized as filler in aggregates for construction blocks or road building. The possibility of leaching trace metals from the ash into ground or surface waters is discussed below.

11.3.2 SLUDGE

Various water treatment units generate sludges (see Figure 11-2) of organic and inorganic origin. The settler-clarifier that treats the raw river water generates an inoffensive sludge, which is returned to the river. The sludges generated on treatment of waste water, however, contain contaminants which could possible pollute groundwater if buried with the mine spoils; for example, the sludge generated on treatment with lime of cooling tower blowdown contains sizable amount of zinc. These sludges, therefore, are disposed of in a landfill.

11.3.3 MINE WASTES

The surface mining operation proceeds in an orderly fashion, following an environmentally sound mining plan. The topsoil is removed and stored, then the overburden is stripped and used to refill the previous pit, in combination with the inorganic wastes from the coal cleaning and sizing plant (rocks, clay, and mud) and the vitrified ash from the gasifiers. The mined-out area is restored to approximately the original surface contour, then the topsoil is replaced, fertilized, and reseeded, completing the land reclamation cycle.

The coal cleaning and sizing plant is located in proximity to the mine. This arrangement minimizes the exposure to the air of mine spoils, with consequent negligible oxidation of coal pyrites to oxygenated sulfur acids.

11.4 NOISE

Noise control will be an integral part of the layout and design of the POGO commercial plant. The Occupational Safety and Health Act of 1970 regulates the amount of weighted noise a worker may be exposed to, in order to protect him from ear damage. Local codes ususally regulate the level of noise that an industrial plant is permitted to generate, at the property line, above the normal ambient background level. The applicable regulations and codes will be used as the design bases for noise control in plant design and layout.

Special attention will be given to the coal gasifier and oxygen plant fans, compressors, and pressure letdown valves. The sound exposure standards will be met by a combination of noise-reduction engineering techniques, such as soundproofing of turbines, silencing of valves, and use of sound and

vibration absorption materials. Process units not requiring close observation and capable of high noise levels, such as oxygen compressors, will be barricaded.

11.5 SPECIFIC ENVIRONMENTAL ASPECTS

Three specific environmental aspects pertinent to coal conversion, the formation and destruction of metal carbonyls, the fate of trace elements present in coal, and the formation of coal tar carcinogens and biohazards involved, are considered below. General factors and specific applications to POGO coal conversion technology are included.

11.5.1 METAL CARBONYLS

Metal carbonyls form by the reaction of the carbon monoxide with free metals in the 100 to 570°F temperature range. Carbonyls form with all transition metals; nickel, cobalt, and iron carbonyls are most significant, since the metals from which they are derived are used as catalysts or for structural equipment.[10,11] Higher pressures (of the order of 15,000 psi) and the presence of hydrogen favor their formation, while oxygen represses it. They decompose readily in air with half-lives estimated at 10 to 15 seconds for cobalt carbonyl, 10 minutes for nickel carbonyl, and a few hours for iron carbonyl.

These carbonyls are volatile liquids at room temperature. They all exhibit toxicity, directed at the respiratory system. The most harmful among the three carbonyls is the nickel derivative. For this carbonyl only, chronic effects and carcinogenic activity have been observed. Suggested exposure guidelines and chemical formulas are reported in Table 11-6.

Iron, nickel, and cobalt catalysts are used in the POGO process, and low carbon steel is employed for structural equipment. However, at the relatively low pressures and high temperatures prevailing, no metal carbonyls are expected to be formed. In shutdown operations, however, conditions under which metal carbonyls can form may be experienced for short periods of time. In these cases, the normal safe practice of flaring vent streams, along with operation of all contaminant removal systems, will prevent release of carbonyls to the atmosphere. Plant personnel who may be entering vessels or handling catalysts, however, will need to be trained in the proper procedures and supplied with adequate protective equipment to safeguard their health.

Table 11-6 - Suggested Exposure Guidelines
for Metal Carbonyls (from Reference 10)

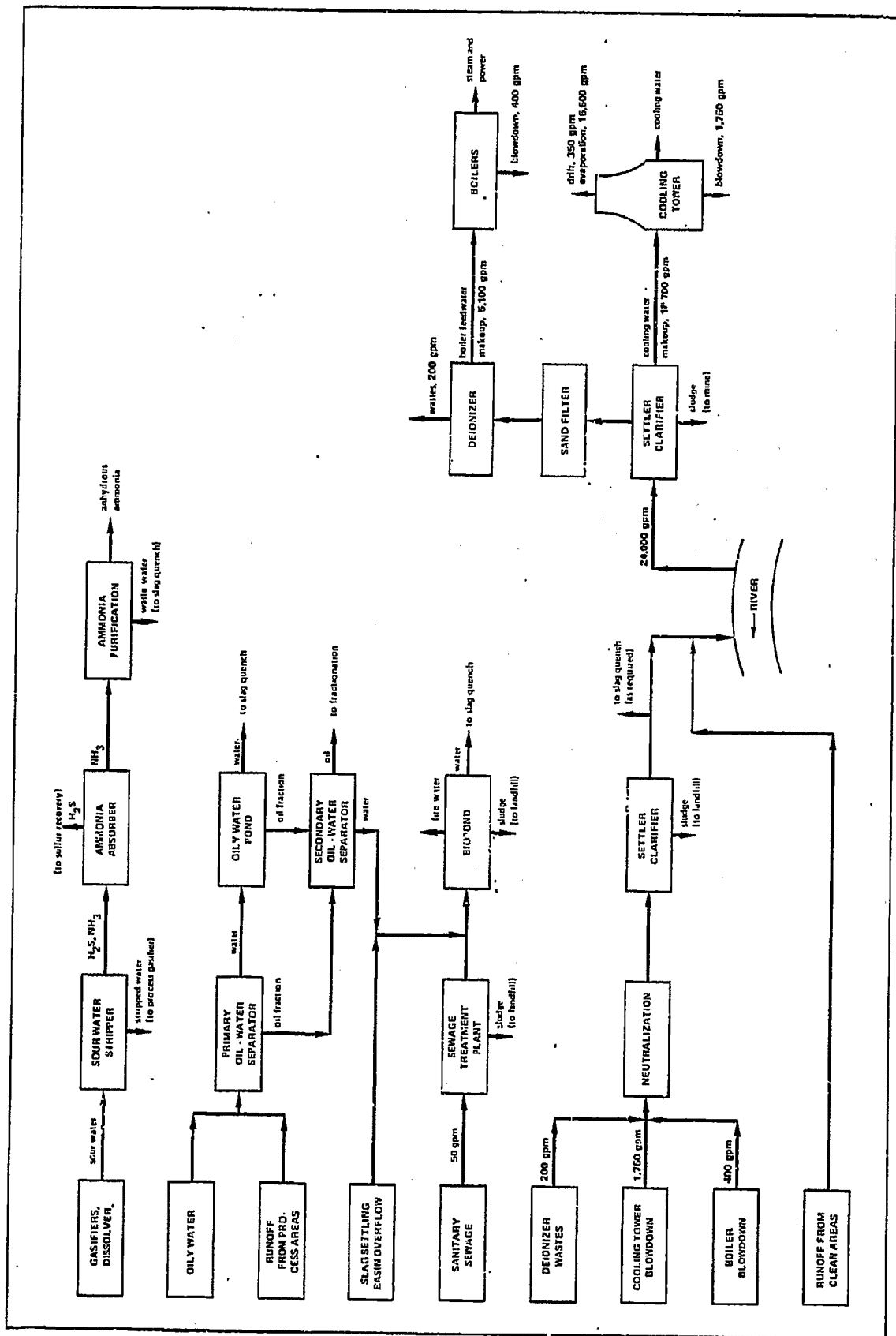| Metal Carbonyl	Air Concentration (ppm)	
	Single Short Term Exposure	Eight-Hour Day
$Ni(CO)_4$	0.04	0.001
$Co(CO)_x + CoH(CO)_4$	0.10	-
$Fe(CO)_5$	0.10	0.01

Figure 11-2 - Block Flow Diagram
Water Treatment and Supply

11.5.2 TRACE ELEMENTS

Due to its organic origin and its intimate commixture with crustal formations, coal contains a large number of elements in minor or trace quantities. Actually, out of 92 known nontransuranic elements, only 14 have not yet been found in coal.

Average amounts of trace and other elements for 82 coals from the Eastern Region of the Interior Coal Province are shown in Table 11-7. These values were developed during a recent study[12] carried out with thorough analytical procedures; the coals analyzed were mainly composite face channel samples.

A number of studies have analyzed the behavior of trace elements in coal-fired power plants.[13,14] In general, the elements have been divided into two groups, the ones appearing mainly in the bottom ash (elements or oxides having lower volatility) and those appearing mainly in the fly ash (elements or oxides having higher volatility). For power plants using dry particulate collection devices (e.g., electrostatic precipitators), it was believed that the most volatile elements, such as mercury and selenium, could actually escape at the elemental state with the flue gas. Wet scrubbers, however, were believed capable of removing most of the elements from the gas streams and transferring them to the liquid effluent.

Very few data are available for coal conversion plants. A study on trace element disposition for the Sasol (South Africa) facility, reported by the Los Alamos Scientific Laboratory[15] was able to follow the partitioning of trace elements between solid residue (ash), liquid streams, and gases. Among the elements studied, lead, arsenic and beryllium were found mainly in the ash, selenium and tellurium in the liquid streams, fluorine two-thirds in the ash and one-third in the liquids. Mercury was found present in all phases, but concentrated mainly in the gas; however, 50% of the mercury and 17% of the beryllium could not be accounted for.

The possibility of leaching of trace metals from the ash into ground or surface waters has been questioned. Experimental studies have been carried out on the leaching of power plant fly ash or unslagged bottom ash;[16] the studies showed that selenium, chromium, and boron, and occasionally mercury and barium, were released on simulated leaching, and the concentrations reached exceeded the values recommended by EPA for public water supplies.

An on-going study at the University of Montana[17] is investigating leaching of trace elements from solid residues of coal conversion plants under neutral, acidic, and basic conditions. Preliminary results indicate that manganese, mercury, and nickel are occasionally released in amounts exceeding recommended potable water standards. The study is hampered by the unavailability of typical residue specimens.

In the POGO plant, essentially no particulates from coal combustion escape into the atmosphere. Particulate streams, wet or dry, are returned to the bottom of the gasifier, where ash and salts melt and are removed as slag. Any eventual dispersion of the elements present in the slag depends on the possibility of leaching. Possibly, slagged ash features a glass matrix which

Table 11-7 - Mean Analytical Values for 82 Coals from
the Illinois Basin (From Reference 12)[a]

Constituent	Mean	Constituent	Mean (%)
As	14.91 ppm	Cl	0.15
B	113.79 ppm	Fe	2.06
Be	1.72 ppm	K	0.16
Br	15.27 ppm	Mg	0.05
Cd	2.89 ppm	Na	0.05
Co	9.15 ppm	Si	2.39
Cr	14.10 ppm	Ti	0.06
Cu	14.09 ppm	ORS	1.54
F	59.30 ppm	PYS	1.88
Ga	3.04 ppm	SUS	0.09
Ge	7.51 ppm	TOS	3.51
Hg	0.21 ppm	SXRF	3.19
Mn	53.16 ppm	ADL	7.70
Mo	7.96 ppm	MOIS	10.02
Ni	22.55 ppm	VOL	39.80
P	62.77 ppm	FIXC	48.98
Pb	39.85 ppm	ASH	11.28
Sb	1.35 ppm	Btu/lb	12748.91
Se	1.99 ppm	C	70.69
Sn	4.56 ppm	H	4.98
V	33.13 ppm	N	1.35
Zn	313.04 ppm	O	8.19
Zr	72.10 ppm	HTA	11.18
Al	1.22 %	LTA	15.22
Ca	0.74 %		

[a]Abbreviations other than standard chemical symbols: organic sulfur
(ORS), pyritic sulfur (PYS), sulfate sulfur (SUS), total sulfur (TOS),
sulfur by X-ray fluorescence (SXRF), air-dry loss (ADL), moisture (MOIS),
volatile matter (VOL), fixed carbon (FIXC), high-temperature ash (HTA),
low-temperature ash (LTA).

would inhibit leaching. Leaching experiments using the slag generated by a slagging gasifier, such as the Bi-Gas pilot plant or a Koppers-Totzek unit, would be very useful.

The major concern, therefore, is to identify trace elements which may be occurring in the gaseous state. The reducing atmosphere present in the middle and top part of the gasifier may also favor different combinations, absent in the oxidizing atmosphere of a power plant boiler.

Among the trace elements with recognized toxic properties present in the coal, high volatility elements (beryllium, mercury, and lead), do not form gaseous hydrides, will condense on cooling, and very likely be removed by the aqueous condensates formed on gas cooling and/or purification. Arsenic, antimony, and selenium have lower volatility, but can form gaseous (covalent) hydrides, arsine, stibine, and hydrogen selenide. These hydrides however, have stability characteristics, which preclude their formation at the temperature and pressure prevailing in the POGO gasifier. From general chemical principles, it would appear, therefore, that harmful trace elements are not released to the atmosphere. Experimental confirmation, however, is desirable, especially for mercury, and should be obtained from specific pilot plant studies.

11.5.3 COAL TAR CARCINOGENS AND BIOHAZARDS INVOLVED

Of particular interest in coal conversion projects is the possible formation of carcinogenic compounds on hydrogenation and pyrolysis of coal. These compounds are polynuclear aromatic hydrocarbons and heterocyclics usually found in coal tars and coal-derived oils with boiling points higher than 500°F.

Oils and tars are not expected to be formed under the operating conditions of the entrained gasifiers used in the POGO plant. The dissolver and pyrolyzer trains, however, handle coal-derived oils, and will therefore require strict application of industrial hygiene practices.