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**A COMPARATIVE STUDY OF EFFLUENTS AND THEIR CONTROL
FROM FOUR DRY ASH LURGI GASIFICATION PLANTS**

Executive Summary

By
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July 1978

Work Performed Under Contract No. EY-76-S-02-4035

Engineering Experiment Station
University of North Dakota
Grand Forks, North Dakota

U. S. DEPARTMENT OF ENERGY

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NOTICE

This report consists of three major sections:

- * Executive Summary, A Comparative Study of Effluents and Their Control From Four Dry Ash Lurgi Gasification Plants, Bulletin No. 78-07-EES-01 A
- * A Comparative Study of Effluents and Their Control From Four Dry Ash Lurgi Gasification Plants, Bulletin No. 78-07-EES-01 B
- * Supplementary Data, A Comparative Study of Effluents and Their Control From Four Dry Ash Lurgi Gasification Plants, Bulletin No. 78-07-EES-01 C

The quantity of data collected in the course of this study required that it be handled through the use of a computer program. The data were analyzed utilizing tables formed by this program. On the basis of this analysis, data were selected and reported in the main volume, Bulletin No. 78-07-EES-01 B. The supplementary data volume contains the data that were collected and the computer program used to analyze those data.

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1.0 BACKGROUND

The four coal gasification plants reviewed in this study are the ones proposed by El Paso Natural Gas Pipeline Company and the WESCO Gasification Company in New Mexico, and the Natural Gas Pipeline Company of America and the ANG Coal Gasification Company in North Dakota. This study was undertaken to review the nature and amounts of the various effluents emitted into the environment, the capital and operating costs of the gasification plants, to determine the costs of controlling the undesirable effluents into the environment, to review the water treatment facilities and pollution control technologies and to identify the control technology research needs.

The four gasification plants will be quite similar as to the process and the quantity of synthetic natural gas (SNG) produced. Each plant proposes to manufacture 250 MMSCFD of pipeline quality SNG containing approximately 96 mole % methane with a calorific value of 980 Btu/SCF. The plants in New Mexico will be using New Mexico subbituminous coal and the plants in North Dakota propose to utilize North Dakota lignite. All plants propose to use dry ash Lurgi gasifiers to produce synthesis gas consisting mainly of CO , H_2 , CH_4 , and CO_2 . The gas coming out of the gasifiers is cooled and washed with water. Part of the cooled gas is mixed with steam and sent to a shift conversion unit. This is done to adjust the ratio of CO to H_2 for that required in the methanation reaction. The shifted gas is then recombined with the unshifted gas and then sent through a Rectisol unit to remove all the H_2S , COS , CS_2 from

the gas stream. Part of the CO_2 is also removed in this step. The purified gas is then sent to a methanation unit where the CO , CO_2 , and H_2 are converted to methane. The methanated gas is compressed and moisture and CO_2 removed by passing it through another Rectisol unit and is then compressed to 100 psig and is ready for pipeline distribution.

2.0 MAJOR CONCLUSIONS AND RECOMMENDATIONS

2.1 CURRENT EFFLUENT CONTROL STATUS

Any gasification facility generates three classes of waste: solid, liquid, and gaseous. Control of effluents is generally discussed by class because of the unique characteristic associated with each class. All three classes were investigated in this report in some depth and are discussed below.

Liquid wastes are "controlled"¹ in the sense that there are none. There are no waste water streams from any of the facilities with the exception of ANG's deep well which will be used for brine disposal. All of the water is either treated for reuse or evaporated. There is little published data concerning the characteristics of water reuse treatment systems for coal gasification facilities. There is a high probability that the existing technology can be used to meet the zero discharge requirement and provide water for reuse.

Gaseous emissions are under tight state standards in New Mexico and federal standards and guidelines in North Dakota. Controlled substances are NO_x , non-methane Hydrocarbons (HC), COS, SO_2 , CO, and particulates. There is a good probability that the federal sulfur standards and guidelines can be met or exceeded (lower emission) with satisfactory operational characteristics. The New Mexico sulfur standards are considerably tighter and will be difficult to meet or exceed with existing equipment while maintaining satisfactory operating

¹The words "controlled" and "uncontrolled" in this context are taken to mean regulated or not regulated by a governmental agency; e.g., emission standards.

characteristics and reasonable cost. Hydrocarbon (HC) and carbon-monoxide emissions guidelines and standards (both federal and state) are somewhat easier to meet than the sulfur standards. The control method used is oxidation, which can exact a penalty in operating efficiency due to the fuel gas requirement. Claus and Stretford tail gas streams in New Mexico may have to be scrubbed both for COS and SO₂ control. A Stretford system has been installed in SASOL and operated successfully. Both the SASOL data and unpublished data indicate that a Stretford can be operated in a Lurgi dry ash gasification environment.

Solids wastes and sludges are, at this time, "uncontrolled."² There is, however, significant research being conducted to establish the probable impact of solid waste disposal and to establish techniques to minimize the potential impact. Present permitting requirements force examination of and approval of the mining, solid waste disposal, and reclamation plans for each facility. The potential for disposing of some of the plant's waste water in the sludges in the mined area is high. This practice, if implemented, will probably precipitate controls on sludge disposal. Existing waste water treatment technology could probably treat sludge additive liquids to environmentally acceptable limits prior to disposal. Technology for post-disposal treatment does not exist.

² Ibid.

2.2 CONSIDERATIONS AND REQUIREMENTS FOR FUTURE EFFLUENT CONTROL TECHNOLOGY

The future needs of control technology are difficult to name and virtually impossible to quantify. There are several general areas that must be considered in examining gasification effluent control research needs, they are:

1. Social, political, and economic considerations.
2. Operational considerations.
3. Technical considerations.

2.2.1 Social, Political, and Economic Considerations

Social pressures for a clean environment are, in the view of the authors, likely to remain in place. Local politics particularly at the town, county, and state levels are likely to cause serious delays in the permitting process for gasification facilities to be constructed. This is particularly true of the western coals which are largely politically controlled by agriculturally based economies. In addition, the air quality level in the western regions is likely to be Class I or Class II. Both of these factors will tend to force plants in the west to utilize best available control technology and may cause some plant retrofitting. Trace metals have high visibility both at the state and national (EPA) levels. Although sound justification for controlling trace element emissions is absent at this time, proposals are being made (particularly by plant opponents) that such emissions, if they occur, be controlled.

Another tool now being widely used by the government to make permit decisions is atmospheric computer modeling. Consequently, the

emission requirements from coal burning/processing facilities are being specified by the air quality requirements rather than by the emission standards. Based upon computer modeling, a large fraction of the available air quality space in North Dakota (Class II) has already been used. The use of computer modeling may represent a serious hindrance to both the development of appropriate control technology and development of the industry itself.

On the average, the fixed capital investment required for environmental control is 50 million dollars (1973) which accounts for about 16 percent of the total fixed capital investment. Direct operating costs average 13 percent of the plant's operating costs (see Table 1). Consequently, the consumer must, on the average, pay a 10 to 15 percent incremental cost increase for environmental control of these facilities.

TABLE 1

SUMMARY OF FIXED CAPITAL INVESTMENT (FCI) AND
DIRECT OPERATING COSTS (DOC) FOR
EACH GASIFICATION FACILITY (1973 DOLLARS)

	<u>El Paso</u>	<u>Natural</u>	<u>WESCO</u>	<u>ANG</u>
FCI (MM \$)	19.463	108.408	57.942	30.215
FCI (% of total)	5.449	32.426	17.338	8.881
DOC (MM \$)	8.257	9763.	7.770	5.832
DOC (% of total)	13.258	15.912	12.951	11.823

It is likely that standards will continue to follow control technology development rather than lead it because of the hearing system used to set standards. The predominant social, political, and

economic considerations are those that control the construction permitting process and the techniques that are used to predict air quality conditions for permitting purposes.

2.2.2 Operational Considerations

The care with which a 250 MMSCFD coal gasification facility is operated will determine its environmental acceptability. The control technologies being used to control gaseous emissions are well established, but are somewhat unproven in the gasification environment. A delicate operational balance between process and sulfur environmental control requirements may exist and depends upon the successful use of coal blending techniques. Although blending is used in power plants, little experience in the gasification environment is available. The control instrumentation required to carry out a coal blending operation exists.

British Gas has completed some studies on Stretford plants on a laboratory scale with favorable results indicating that blending schemes could be used. Consequently, the mining plan and coal blending scheme used has an impact on the selection, design, and operation of sulfur recovery equipment. This fact should be considered in the promulgation of regulations, particularly at the state level. That is, a state's regulations could reflect the variability of the sulfur content of its coal.

2.2.3 Technical Considerations

Areas of technical concern that are germane to environmental control technology are:

1. Odor control.
2. Control of biologically hazardous materials.
3. Control of volatile trace element and trace compound effluents.

4. Development of the multimedia environmental goals (MEG's).
5. Solid waste and sludge disposal.
6. Water treatment and reuse.

At the present time the federal government is supporting research and actively pursuing all of the above areas. None, with the possible exception of the first, are likely to impact plant operation. All have the distinct possibility of increasing the required capital investment.

Biologically hazardous materials can usually be controlled by combustion or containment. It is likely that the trace element compounds that are volatile could be removed by tail gas scrubbing units, although these units are not ordinarily used for this purpose. Development of the MEG's is an extremely important step and is likely to point out control technology needs clearly once a plant has been built and a good characterization of its effluent streams is available. Solid waste and sludge disposal techniques are currently being investigated. Hydrological isolation techniques either exist or can probably be developed should an impact be found due to leaching or sludge liquid drainage. Water treatment techniques for internal water reuse will probably work but will need the development work that is currently being carried out by DOE.

Of all of the above areas, odor control is perhaps the most innocuous. The effluent quantities and concentrations involved are extremely small and in some cases difficult to measure. It is clear that there will be an odor associated with the plants. What it will be and how it is to be controlled are unknown.

2.3 RECOMMENDATIONS

The following recommendations represent the opinions of the authors. They do not infer that the existing control technology being proposed for the four plants is inadequate. In fact, it is the authors' opinions that the existing control technology is adequate and that it can and probably will meet existing regulations and guidelines. The recommendations given below are based upon current research and the state of knowledge dealing with effluents.

- *It is recommended that a program be implemented to mesh the MEG's with the characterization program from the DOE gasification program. The goal of this program should be to prioritize effluents as candidates for control based impact upon MEG data and quantity considerations.
- *A serious investigation into the verification and use of air quality modeling programs is needed if they are to become the limiting element in the permitting process.
- *Basic research in the biological sciences is needed to ensure that appropriate gasification related EPC's and MATE's are generated. DOE and EPA should cooperate in this area and utilize DOE's gasification program as a source of effluents.
- *A program should be initiated to establish and characterize the probable odors from a gasification facility.
- *The best available control technology for pyridine, HCN, and phenols needs to be identified and examined with respect to potential gasification needs.
- *The use treated wastewater as cooling tower make-up should be substantiated with field tests. The problem of cooling tower "drift" requires special assessment and will impact air quality.
- *CaSO₃ based sludges associated with limestone scrubbing operations for the boiler plant (which may be hazardous under RCRA) tend to be "muds" which fluidize when wet. Precautionary blending and perhaps fixation procedures will be required when these materials are disposed with mine tailings. Field to verification of these procedures should be completed.

*The use of evaporation ponds poses a series of potential problems: (1) odor and release of trace volatiles contained by the wastes, (2) effectiveness and use during severe cold spells, and (3) ultimate disposal of bottom sludges during normal plant operation and at the decommissioning of the plant. These potential difficulties need to be addressed through field experimentation and verification.

*The Stretford and Claus units will be operating at conditions somewhat beyond their standard ranges (high for Stretford and low for Claus). They deserve special characterization and study.

*Disposal of wastewater treatment sludges and other process wastes in mine restoration operations requires close scrutiny. Attention should be given to the effect of leachable constituents associated with the disposal of blowdown sludges.

3.0 EFFLUENT DISTRIBUTION

Table 2 gives the summary of various effluents that would be emitted into the environment from the four plants. Only 22 of the 60 effluents analyzed in the study are reported here. The gaseous effluents and particulates would be emitted into the atmosphere, the fly ash, boiler ash, gasifier ash and sludges would be disposed of by mine burial. One plant (ANG) proposed to dispose of blowdown brines by deep well injection. There will be no boiler ash or fly ash from the El Paso plant because low Btu gas, which is generated by gasifying coal, will be used to fire the boilers. The ANG plant does not have any boiler ash because it will be buying most of its steam from neighboring Basin Power Cooperative. Some steam will be produced at ANG in supplementary boilers using tar, tar oils, and naphtha and, hence, some fly ash will be emitted.

The emission of CaSO_4 , CaSO_3 , CaCO_3 , Na_2SO_4 , and Na_2SO_3 depends on the flue gas desulfurization process used. El Paso and ANG plants do not have any flue gas desulfurization processes and hence, they will not emit these sulfates, sulfites, or carbonates. Natural proposes to use the FMC process, consequently, and will have to dispose of CaSO_3 , Na_2SO_3 , and Na_2SO_4 . WESCO plans to use the Chiyoda Thoroughbred 101 Process and will have to dispose of CaCO_3 and CaSO_4 .

The gaseous emissions from the coal locks were considered. This occurs when the lock gas used to compress the coal lock to gasifier pressure is displaced when coal is being charged into the lock. Most of this displaced gas is emitted into the atmosphere. None of the plants have indicated any system to contain these emissions.

TABLE 2

SUMMARY OF ESTIMATED EMISSIONS OF VARIOUS EFFLUENTS
FROM THE FOUR GASIFICATION FACILITIES
(tons/day)

Effluent	El Paso		WESCO		Natural		ANG		To Deep Well Injection
	To Atm	To Mine	To Atm	To Mine	To Atm	To Mine	To Atm	To Mine	
Coal Dust	0.1412	-	0.0124	-	0.1473	-	1.2192	-	-
Refuse	-	1,680	-	2,263	-	-	-	-	-
Sludge + Water	-	1,147	-	1,413	-	437	-	740	3,052
Boiler Ash	-	-	-	135	-	151	-	-	-
Fly Ash	-	-	-	411	-	361	-	6.24	-
Gasifier Ash	-	5,439	-	6,534	-	2,159	-	1,763	-
Unreacted C	-	286	-	-	-	-	-	-	-
Particulates	0.5530	-	1.2160	-	2.177	-	1.5688	-	-
CaSO ₄ ·2H ₂ O	-	-	-	215	-	-	-	-	-
CaSO ₃ ·2H ₂ O	-	-	-	-	-	179	-	-	-
CaCO ₃	-	-	-	53	-	-	-	-	-
Na ₂ SO ₃	-	-	-	-	-	2.5	-	-	-
Na ₂ SO ₄	-	-	-	-	-	9.6	-	-	-
O ₂	12,540	-	1,723	-	2,391	-	1,761	-	-
N ₂	82,544	-	53,135	-	60,148	-	40,840	-	-
H ₂ O Vapor	31,644	-	29,712	-	39,968	-	30,399	-	-
CO ₂	27,805	-	30,399	-	34,171	-	26,945	-	-

TABLE 2 (Continued)

<u>Effluent</u>	<u>El Paso</u>		<u>WESCO</u>		<u>Natural</u>		<u>ANG</u>		<u>To Deep Well Injection</u>
	<u>To Atm</u>	<u>To Mine</u>	<u>To Atm</u>	<u>To Mine</u>	<u>To Atm</u>	<u>To Mine</u>	<u>To Atm</u>	<u>To Mine</u>	
Naphtha	0.224	-	-	-	-	-	-	-	-
Fatty Acids ^(b)	1.0707	-	0.3867	-	0.7626	-	-	-	-
Phenolics ^(c)	0.1165	-	0.0033	-	0.3648	-	-	-	-
Pyridines ^(d)	0.0067	-	-	-	-	-	-	-	-
Thiocyanates ^(e)	0.0893	-	0.0032	-	0.179	-	-	-	-

(a) Estimated as NO₂

(b) Estimated as acetic acid

(c) Estimated as phenol

(d) Estimated as pyridine

(e) Estimated as HSCN

There will be emission of trace compounds, such as fatty acids, phenolics, pyridines, and ammonia, from cooling towers. These compounds are present in the cooling water which is made up of effluent water from various sources, and they will be vaporized and emitted into the air in the cooling tower. Most of these compounds have an odor when present even in minute amounts. Consequently, there will be a definite odor emitted by the facilities.

H_2S is removed from the main product gas stream by the Rectisol process in all four plants. The H_2S contained in the off-gases from the Rectisol unit is proposed to be converted to elemental sulfur by the Stretford process in the El Paso and the ANG plants and by a combination of the Stretford and Claus processes in the WESCO and Natural plants. The ADIP unit will be used to concentrate the H_2S in the feed gas to the Claus unit.

The vent gases from the ADIP, Claus, and Stretford units contain hydrocarbons, CO, H_2 , residual H_2S , COS, and H_2 . These gases are controlled by incineration, either in a boiler, superheater, or in a catalytic incinerator.

4.0 ECONOMIC ANALYSIS

Table 3 shows the installation costs, the gross capital investment, the operating costs, the allowable revenue, and the selling price of the SNG for the four plants based on 1973 dollars. The costs for the four plants will be similar because basically the plants are similar in design and size. It was assumed that 25 percent of the capital investment will come from equity capital and 75 percent from debt capital.

Tables 4 and 5 list the capital investment, the direct operating costs and the quantity of effluent controlled for the various effluent control systems used in the plant. The effluent control costs for the WESCO plant are the highest and constitute the largest fraction of the total plant cost. This is due to very high costs for SO₂ control. El Paso has the lowest cost since it does not have any flue gas desulfurization units or electrostatic precipitator. Extra gasifiers will be used at the El Paso plant to produce low sulfur fuel gas for use in the boiler. It is interesting to note that the fraction of money spent for environmental control varies from 5.3% (El Paso) to 32.3% (Natural). If the cost of the additional gasifiers are credited toward environmental control, then ANG becomes the plant with lowest environmental cost at 8.8%.

TABLE 3

SUMMARY OF THE INSTALLATION COSTS, CAPITAL INVESTMENT,
OPERATING COSTS AND ALLOWABLE REVENUE FOR THE PROPOSED GASIFICATION PLANTS
(1973 DOLLARS)

	<u>El Paso</u>	<u>WESCO</u>	<u>Natural</u>	<u>ANG</u>
16 2066 Total Installation Cost, 10 ⁶ dollars	357.22	334.33	334.22	340.23
Total Capital Investment, 10 ⁶ dollars	491.08	459.62	459.48	467.90
Total Operating Cost, 10 ⁶ dollars/year	87.02	87.58	85.51	73.16
Total Allowable Revenue, 10 ⁶ dollars/year	126.76	125.84	126.33	121.02
Selling Price of SNG, \$/1000 SCF	1.388	1.378	1.383	1.326

TABLE 4

SUMMARY OF THE FIXED CAPITAL INVESTMENT (FCI), YEARLY DIRECT OPERATING COSTS (DOC) FOR EFFLUENT CONTROL, AND THE AMOUNT OF EFFLUENT CONTROLLED FOR GASIFICATION PLANTS

(FCI and Yearly DOC in MM dollars, 1973 dollars)

		El Paso		WESCO			Natural		ANG			
Effluents	FCI	DOC	Qty Control- ed (ton/day)	FCI	DOC	Qty Control- ed (ton/day)	FCI	DOC	Qty Control- ed (ton/day)	FCI	DOC	Qty Control- ed (tons/day)
Ash & Sludge	7.868	1.209	8552	7.956	1.322	11024	4.746	0.981	3299	3.923	0.648	2509 (a)
Coal Dust & Particulates	0.376	0.698	16.812	6.916	1.035	421.64	7.472	0.973	376.1	4.051	0.915	20.4
H ₂ S	8.612	5.959	201.114	15.293	2.170	212.75	16.978	2.403	237.75	22.241	4.269	236.51
SO ₂	-	-	0.0	78.243	5.236	81.45	27.1	3.251	75.58	-	-	0.0
Hydrocarbons	1.545	0.235	110.4	0	0	218.98	1.286	0.126	267.6	0	0	266.56
CO	0.318	0.0476	52.56	0	0	130.7	0.0822	0.00814	14.81	0	0	6.72
H ₂	0.725	0.107	6.816	0	0	19.8	0.183	0.0181	2.255	0	0	0.749
COS	0.019	0.00157	1.981	0	0	3.712	0.045	0.0047	4.43	0	0	6.185
CS ₂	0.00032	0.00005	0.0691	0	0	0.0	0.0035	0.00033	0.284	0	0	3.47
S Vapor	-	-	0.0	-	-	0.0	0.046	0.0048	0.238	-	-	0.0
Total	19.463	8.257		108.408	9.763		57.942	7.770		30.215	5.832	

(a) Does not include 3052 tons/day of sludge and water sent to deep well injection.

TABLE 5

SUMMARY OF THE FIXED CAPITAL INVESTMENT (FCI) AND YEARLY DIRECT OPERATING COSTS (DOC) FOR EFFLUENT CONTROL EXPRESSED AS PERCENTAGE OF TOTAL COSTS FOR THE FOUR GASIFICATION PLANTS

Effluents	El Paso		WESCO		Natural		ANG	
	FCI(%)	DOC(%)	FCI(%)	DOC(%)	FCI(%)	DOC(%)	FCI(%)	DOC(%)
Ash & Sludges	2.203	1.941	2.380	2.155	1.420	1.635	1.153	1.314
Coal Dust & Particulates	0.105	1.121	2.069	1.687	2.236	1.622	1.191	1.855
H ₂ S	2.411	9.568	4.574	3.537	5.080	4.005	6.537	8.654
SO ₂	-	-	23.403	8.533	8.108	5.418	-	-
Hydrocarbons	0.433	0.377	0	0	0.385	0.210	0	0
CO	0.089	0.076	0	0	0.025	0.0136	0	0
H ₂	0.203	0.172	0	0	0.055	0.0302	0	0
COS	0.005	0.003	0	0	0.014	0.008	0	0
CS ₂	0.000	0.000	0	0	0.001	0.001	0	0
S Vapor	0	0	0	0	0.014	0.008	0	0
Total	5.449	13.258	32.426	15.912	17.338	12.951	8.881	11.823

5.0 WATER TREATMENT AND ECONOMICS

All four plants cited have incorporated the concept of zero liquid effluent discharge in their plant designs to meet the stipulations in P.L. 92-500; consequently, no liquid effluent discharge into surface waters is planned. For Natural, El Paso, and WESCO, the only liquid effluent leaving the plant will be the water contained in ashes and in sludges to be buried on the mine sites. In the case of ANG, other liquid effluent streams released to the environment will be the water treatment effluent and boiler blowdown streams, which are to be disposed of in deep wells.

All plants emphasize in-plant water reuse. Since all of the plants will be located in semi-arid or arid climates, water conservation and reuse will help to alleviate the impact of high water demand on the region, as well as to achieve the goal of zero pollutant discharge requirements. Major items of water reuse include cooling water make-up, and ash quenching and handling. In two of the proposed designs, Natural and WESCO, biological treatment of aqueous effluent from the Phenosolvan plant has been proposed before reuse as cooling water make-up and in the other two, ANG and El Paso, this effluent will be used directly as cooling water make-up. All four gasification plants propose to use surface water for their source of water supply.

5.1 PROPOSED SYSTEMS AND EFFLUENT CHARACTERISTICS

The water treatment systems as proposed by the four coal gasification plants and the water stream characteristics as contained in the companies' Environmental Impact Statements are described below.

Natural Plant - The 67 gpm of sanitary wastes are treated in a package waste treatment unit. The 4528 gpm of Phenosolvan effluent and a portion of the utility and storm waters of the 50 gpm flow are treated in a process water treating unit where an activated sludge process is employed to remove organics present in the liquid streams. The water treatment facilities are shown in Figure 1. A characterization of the influent and effluent process water streams to the treating unit, as listed in the Natural EIS report, are shown in Table 6.

ANG Plant - The sanitary wastes are treated in a package biological treatment unit. The Phenosolvan effluent does not receive any further treatment and is used, together with treated sanitary wastes, as cooling make-up water. Biological treatment of the Phenosolvan effluent is not proposed for the ANG plant. The water treatment system is shown in Figure 2. Deep well disposal has been proposed for the disposal of 90 gpm of regeneration streams from the softener and 174 gpm of blowdown stream from the low pressure steam system. The composition of liquid streams for deep well disposal is listed in Table 7.

FIGURE 1. WATER STREAMS AND TREATMENT SYSTEMS, NATURAL PLANT.

TABLE 6

CHARACTERIZATION OF PROCESS WATER TREATING UNIT
INFLUENT AND EFFLUENT FOR THE NATURAL PLANT

Component	Influent Concentration (mg/l)	Effluent Concentration (mg/l)
Ca	1,261	188
Mg	-	2
Na	52	52
NH ₄	158	100
HCO ₃	-	140
Cl	326	326
SO ₄	-	47
NO ₃	-	182
Free CO ₂	-	25
Total PO ₄	-	22
Si	-	1
Total Dissolved Solids	-	1,093
CN	10	5
Phenols	237	94
Fatty Acids	2,970	75
NH ₃	100	-
pH	10	6

NOTE: Characterization data based on Natural's EIS report.

FIGURE 2. WATER STREAMS AND TREATMENT SYSTEMS, ANG PLANT.

TABLE 7

COMPOSITION OF LIQUID STREAMS FOR
DEEP WELL DISPOSAL FOR ANG PLANT

<u>Constituents</u>	<u>Concentration (mg/l)</u>
CaSO ₄	540
MgSO ₄	460
Na ₂ SO ₄	6,460
NaCl	2,770
NaHCO ₃	110
CaCl ₂	860
MgCl ₂	730

El Paso Plant - The Phenosolvan Unit receives gas liquors from both oxygen gasification and fuel gas production. The Phenosolvan effluent flows to a steam stripping unit for the removal of ammonia from the gas liquor. The flow rate for the stripped gas liquor is 2706 gpm, of which 2377 gpm will be used as cooling water make-up and 329 is used as ash handling water. Biological treatment or other secondary treatment is not proposed for the El Paso plant. Figure 3 depicts the water treatment systems of the El Paso plant.

WESCO Plant - The Phenosolvan effluent stream (2810 gpm), combined with sewer flows and excess storm water, will first be treated in oil separators, to be followed by air flotation and biological treatment. Removal of entrained oils is achieved in the oil separators and the air flotation units. Organics will be removed in a biological treatment unit. A portion of the biological treatment unit effluent

FIGURE 3. WATER STREAMS AND TREATMENT SYSTEMS, EL PASO PLANT.

(2680 gpm) is to be used for process cooling, the balance for ash quenching, revegetation, road wetting, sulfur pelletizing, and other mine uses. The water treatment system for the WESCO plant is shown in Figure 4.

FIGURE 4. WATER STREAMS AND TREATMENT SYSTEMS, WESCO PLANT.

5.2 WATER TREATMENT REUSE BACKGROUND AND CHARACTERISTICS

Although all four plants have proposed designs for the handling of gasification generated waste waters, the state of the literature indicates that there is a general lack of reliable data on which a reliable design can be formulated. The Department of Energy has recognized this and is supporting research in this area. Much of the literature that is available and is pertinent was generated on the basis of coke facility waste waters. The literature and work are reviewed in depth in the body of the report and are used as the basis for projecting the waste water chemical characterization from the proposed facilities.

The major liquid waste stream in a Lurgi gasification plant is the gas liquor, which has a high concentration of contaminants. In the four proposed plants the gas liquor is treated in the Phenosolvan unit for phenol removal. Since all plants are currently in the planning state, the actual waste samples are not available for laboratory characterization. Estimates of the constituents of influent stream to the Phenosolvan unit for the four proposed plants was calculated on the basis of coke data. These estimated data are summarized in Table 8.

The Phenosolvan influent contains 6591 mg/l of phenolics and 1858 mg/l of fatty acids. About 93 percent of phenolics are estimated to be recovered in the Phenosolvan unit. Effluent from the Phenosolvan unit still contains 430 mg/l of phenolics and 1858 mg/l of fatty acids. Total theoretical oxygen demand is estimated at 5165 mg/l. Estimated effluents based upon coke plant data and a hypothetical plant are shown in Table 9.

TABLE 8

ESTIMATED COMPOSITION OF INFLUENT AND
EFFLUENT STREAMS OF A PHENOSOLVAN UNIT

Parameters	Phenosolvan Influent (mg/l)	Phenosolvan Effluent (mg/l)
S	63.4	63.4
Cl	33.7	33.7
NH ₃	8,173	79.6
Phenolics	6,591	430
Fatty Acids	1,858	1,858
HCN	4.2	4.2
Na	45.4	45.4
P ₂ O ₅ as H ₃ PO ₄	4.8	4.8

TABLE 9

ESTIMATED GASIFICATION PLANT INFLUENT AND
EFFLUENT CHARACTERISTICS OF AN ACTIVATED SLUDGE
SYSTEM BASED UPON COKE PLANT WASTE DATA

Parameters	Influent Concentration (mg/l)	% Removal	Effluent Concentration (mg/l)
S	63.4	95	3.2
Cl	33.7	0	33.7
NH ₃	79.6	50	39.8
Phenolics	430	90	43.0
Fatty Acids	1,858	90	185.8
HCN	4.2	80	0.8
Na	45.4	0	45.4
P ₂ O ₅ as H ₃ PO ₄	4.8	100	0

Capital and operating costs were also estimated for hypothetical water reuse systems. The results of these estimates are given in Table 10.

TABLE 10

ESTIMATED CAPITAL AND OPERATING COSTS
FOR HYPOTHETICAL ACTIVATED SLUDGE SYSTEMS
(1973 DOLLARS)

	<u>El Paso</u>	<u>Natural</u>	<u>WESCO</u>	<u>ANG</u>
Capital Cost, MM \$	6.91	7.07	4.93	4.03
Operating Cost, MM \$/Year	1.62	1.65	1.13	1.11

5.3 DISCUSSION

The current water treatment terminology is adequate to treat liquid streams from the gasification plants as proposed by the four plants; there will be no liquid effluent discharge into the receiving waters. Waters leaving the plant site will include water contained in the ashes and sludges, which possibly will be disposed of at the mine site, and water evaporated from the cooling towers. The major in-plant water reuse is for the cooling make-up water. The use of the cooling tower as a means of disposal of the impaired-quality water in the gasification plants might help to meet the "zero effluent discharge" goal, but the impact on the environment resulting from the air pollutants in the evaporated water needs to be studied.

There is some question concerning the need for biological treatment of Phenosolvan effluent waters. Future designs will probably use Phenosolvan effluent as cooling tower make-up if this practice does not result in unacceptable environmental impact and equipment deterioration. The use of hypothetical activated sludge systems for Phenosolvan water treatment was investigated as the natural alternative to the direct use of these waters.

Operating data for the water treatment system in the plants is lacking at this time. In all likelihood, the operation of such a treatment system will be quite reliable and will meet the plant water-reuse objective.

6.0 ANALYSIS OF EFFLUENT DATA AND DATA RELIABILITY

A considerable quantity of data was generated in the process of completing this study. Sixty (60) possible effluents were analyzed in the design streams for twenty (20) divisions of four (4) plants. In addition to the numerical data for effluent emission quantities, the costs (operational and capital) of control of those effluents, the reliability, and hazard level of the effluents were estimated. The effluents were also compared to the Multimedia Environmental Goals (MEG's) used by the EPA to determine the hazard potential. Eight of the sixty effluents analyzed were found to have an EPA hazard potential and are listed in Table 11. The EPA hazard rating varies from 1 through 30-XXX (least to most hazardous). The reliability data reported in Table 11 represent the authors' judgement of the accuracy of the emission quantity data.

TABLE 11

EFFLUENT QUANTITIES AND DISPOSITIONS THAT HAVE MEG VALUES

Effluent	Plant/ Division	Quantity (TPD)	Quantity Reliability	EPA Hazard Potential	UND Estimated Hazard	(2)
#55 Pyridine	1/19	0.00665	C	15-X	HZ	
#44 Hydrogen Cyanide	1/07	0.1143	C			
			C	15-X	TX	
	1/18	0.572	C			
#48 Hydrogen Sulfide	1/06	0.1532	C			
	2/06	0.0005	C	12	TX	
	3/06	0.0044	C			
	4/06	0.1508	C			
	1/13	0.0058	C			
	3/14	0.0154	A			
#54 Phenols	1/07	0.00006	C	10	HZ	
	1/18	0.00031	C			
	1/19	0.1161	C			
	2/19	0.3648	C			
	3/19	0.0033	C			
#39 Carbon Monoxide	4/04	1.344	B	8	TX	
	1/06	7.1530	C			
	4/06	4.2409	C			
	4/12	3.024	A			
	1/13	0.856	B			
#50 Ammonia	1/19	4.562	C	8	HZ	
	2/19	9.160	C			
	3/19	2.544	C			
#42 Carbon Disulfide	1/13	0.00288	C	8	HZ	
#40 Carbonyl Sulfide	2/06	0.00136	C	4	HZ	
	3/06	0.00120	C			
	1/13	0.0825	C			
	3/14	0.0419	B			

(1) 1: El Paso, 2: Natural, 3: WESCO, 4: ANG

(2) HZ: Hazardous to humans, TX: Toxic to humans