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Project Summary

Environmental Assessment: Source Test and Evaluation Report Koppers-Totzek Process

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TRW, under contract to the Environmental Protection Agency (EPA), is performing a comprehensive environmental assessment of high-Btu gasification and indirect liquefaction technologies. A major portion of this environmental assessment project is to obtain data on operating facilities through Source Test and Evaluation (STE) programs. The ultimate objective of each STE program is to obtain the data necessary to: 1) evaluate environmental and health effects of waste streams or streams that may potentially be discharged from plants designed for U.S. sites, and 2) allow subsequent evaluation of the equipment available or required for controlling these streams.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

An STE program was conducted by TRW on a Koppers-Totzek (K-T) coal gasifier. The EPA's interest in the K-T process stems from two principal factors: first, in the national drive to supplement liquid and gaseous fossil fuels through coal conversion, process economics dictate that the more viable conversion products will be those having the highest unit retail value. The K-T process represents one of the prime candidates for converting raw coal into the intermediate synthesis gas needed to produce these high-value products. Secondly, the K-T process has a lengthy history of successful application to a variety of foreign coals and promises to be equally adaptable over the range of U.S. coals. This factor is particularly important in view of the contrasting lack of demonstrated commercial reliability on the part of the developmental U.S. gasifiers, and is viewed in a very positive light by both conversion project financiers and program managers.

The K-T process operates on an entrained bed principle. It utilizes a high-temperature (1400°-1600°C), atmospheric-pressure reaction fueled by a continuous co-current input stream of coal, oxygen, and steam. The licensor-developer of the Koppers-Totzek gasification process is Krupp-Koppers GmbH (K-K) of Essen, Federal Republic of Germany. As of 1978 there were 54 K-T gasification modules in the world of which 47 were using coal as a feed stock. All of the K-T gasifiers in operation as of 1978 were used entirely to make synthesis gas as an input stream for the production of ammonia. The facility selected for testing was the No. 4 Ammonia Plant at Modderfontein, Republic of South Africa. The plant is owned and operated by AECI, Ltd., and has a design production rate of 1000 tonnes/day of ammonia. The plant was commissioned in 1974. The gasification facility utilizes a bituminous, high volatile B coal that is high in ash (20%), and low in sulfur (1.0%).

Process

The Source Test and Evaluation (STE) program was carried out as a joint effort between TRW and K-K, the licensor and developer of the K-T process. TRW's initial review of the Modderfontein plant, shown schematically in Figure 1, resulted in the selection of 25 streams as necessary to the comprehensive STE goals. Of the 25 streams, summarized in Table 1, nine were actually tested (i.e., streams 7, 15, 16, 32, 33, 38, 40, 46, and 50). The selection of streams for testing resulted from discussions between K-K and TRW in which streams considered proprietary or otherwise restricted were eliminated from the list. The STE thus became limited in scope and focused on the remaining available streams.

The on-site sampling and analysis was performed by K-K. Their overall effort spanned a 3-week period in November 1979. The gas samples were analyzed for the species H_2O, H_2, CO, CO_2, N_2, CH_4, H_2S, COS, CS_2, mercaptans, SO_2, NH_3, HCN, and NO_x. Aqueous samples were analyzed for the standard wastewater tests (e.g., pH, alkalinity, conductivity, BOD, COD, and anions) with a few supplemental wastewater tests also being performed by a local commercial laboratory, McLachlan & Lazar (pty), Ltd.

Wastewater samples were shipped to TRW for comprehensive organic and inorganic analyses per the EPA procedures for Level 1, Level 2, and Priority Pollutants (1, 2, 3). The Level 1 methods provide a broad semi-quantitative survey from which constituents found to be present at potentially hazardous levels are selected for further quantitative examination (Level 2). The Priority Pollutant screening consists of analyses for a specific list of 129 pollutants of concern to the EPA.

All of the data obtained from this STE were used in the EPA's Source Analysis Model/IA, which compares the measured concentrations of the constituents analyzed to the EPA's Discharge Multimedia Environmental Goals (4,5). This model calculates discharge severities based on the constituent concentrations alone (total discharge severity, TDS) and on the concentrations combined with the stream flowrate (weighted discharge severity, WDS). This approach, being used uniformly by all EPA contractors in the coal conversion area, provides a consistent basis for evaluating STE data.

The results of utilizing the SAM/IA approach with the data from the Modderfontein Koppers-Totzek facility are summarized in Figure 2. The two tail gas streams are direct emissions at Modderfontein. The discharge water is the settling pond effluent. Results from the input waters (purified sewage effluent and cooling water) supplied to the gasification facility are also provided for comparison. The data from Modderfontein indicate that the streams tested do not appear to be of particular concern. The discharge severity values obtained are similar to or lower than those obtained on similar streams from other gasifiers (6,7). However, a conclusive determination of health and ecological effects or lack thereof can only be obtained from a combination of chemical and biological tests. Biological tests were not included in this STE.

Note that the discharge severity values of concern result from relatively few constitutents. The TDS and WDS for the two tail gas streams are due primarily to the CO and NH_3 concentrations. The TDS and WDS for the aqueous streams are due mainly to P and Mn and, to a lesser extent, Fe, Cd, Cu, Ni, Pb, and Zn. The reduction in both TDS and WDS for the discharge versus the input waters appears to be due to a decrease in the concentrations of P, Cu, Pb, and Zn. These appear to be lost to the settling pond sludge.

Table 1. *Process Streams Requested for STE Program*

*Stream No.**	*Stream Description*
6	*Coal Bin Purge Gas*
7	*Coal Feed to Gasifier (tested)*
9	*Gasifier Slag*
12	*Gasifier Poke Hole Gas*
15	*Raw Product Gas (tested)*
16	*Input Water, Cooling Water (tested)*
17	*Compressed Raw Gas*
19	*Sulfur-Free Raw Gas*
20	*Compressed Sulfur-Free Gas*
26	*Spent Shift Catalyst*
21	*Shifted Product Gas*
22	*CO_2-Free Product Gas*
23	*Synthesis Gas*
24	*Compressed Synthesis Gas*
25	*Recycled Gas from Synthesis*
28	*Nitrogen Wash Tail Gas*
34	*CO_2 Rich By-Product Gas*
33	*CO_2 Stripper Tail Gas (tested)*
32	*Diluted Rectisol Condensate (tested)*
35	*H_2S Rich By-Product Gas*
38	*H_2S Rewash Column Tail Gas (tested)*
40	*Compressors Condensate (tested)*
48	*Cooling Tower Recycle Wash Water*
46	*Input Water, Purified Sewage Effluent (tested)*
50	*Settling Pond Discharge (tested)*

**Stream numbers correspond to those shown on Figure 1.*

Conclusions and Recommendations

The limited source program conducted at the Modderfontein facility has provided some of the key data needed for the environmental assessment of Koppers-Totzek based synthetic fuel plants which may be built in the U.S. The data obtained do not indicate that any special problems should be encountered in controlling the process effluents to environmentally acceptable levels for plants built in the U.S. Relatively steady state conditions were realized during the test period; thus, most of the samples taken were generally representative of typical plant operation. This in turn indicates

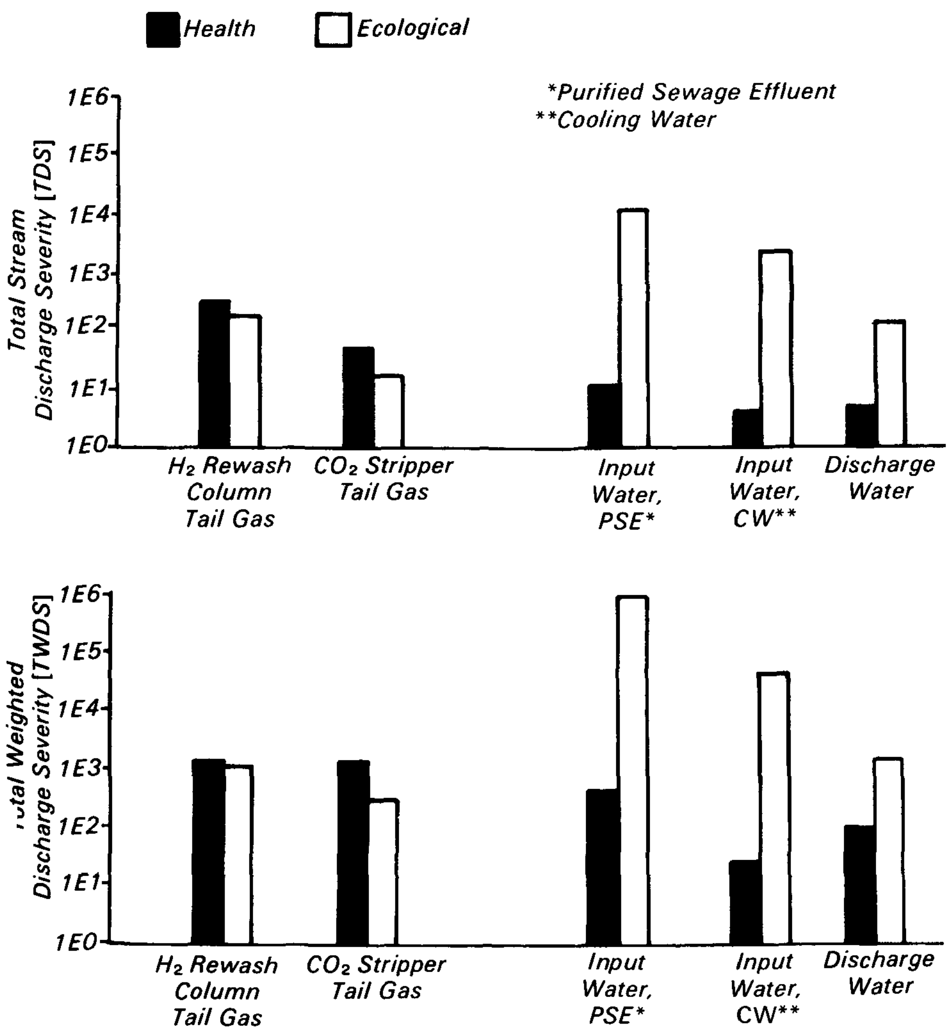


Figure 2. *Summary of SAM/IA results for Koppers-Totzek facility.*

that the data can be used reliably, as intended. One exception was the Rectisol unit which apparently was not operating properly at the time; hence, data on Rectisol tail gas characteristics are not believed to be typical.

Except for the Rectisol unit tail gases, additional sampling of the streams which were the subject of the initial test program is not expected to yield information other than of a confirmatory nature. Hence only limited additional sampling of these streams is suggested in conjunction with aqueous stream sampling as outlined below.

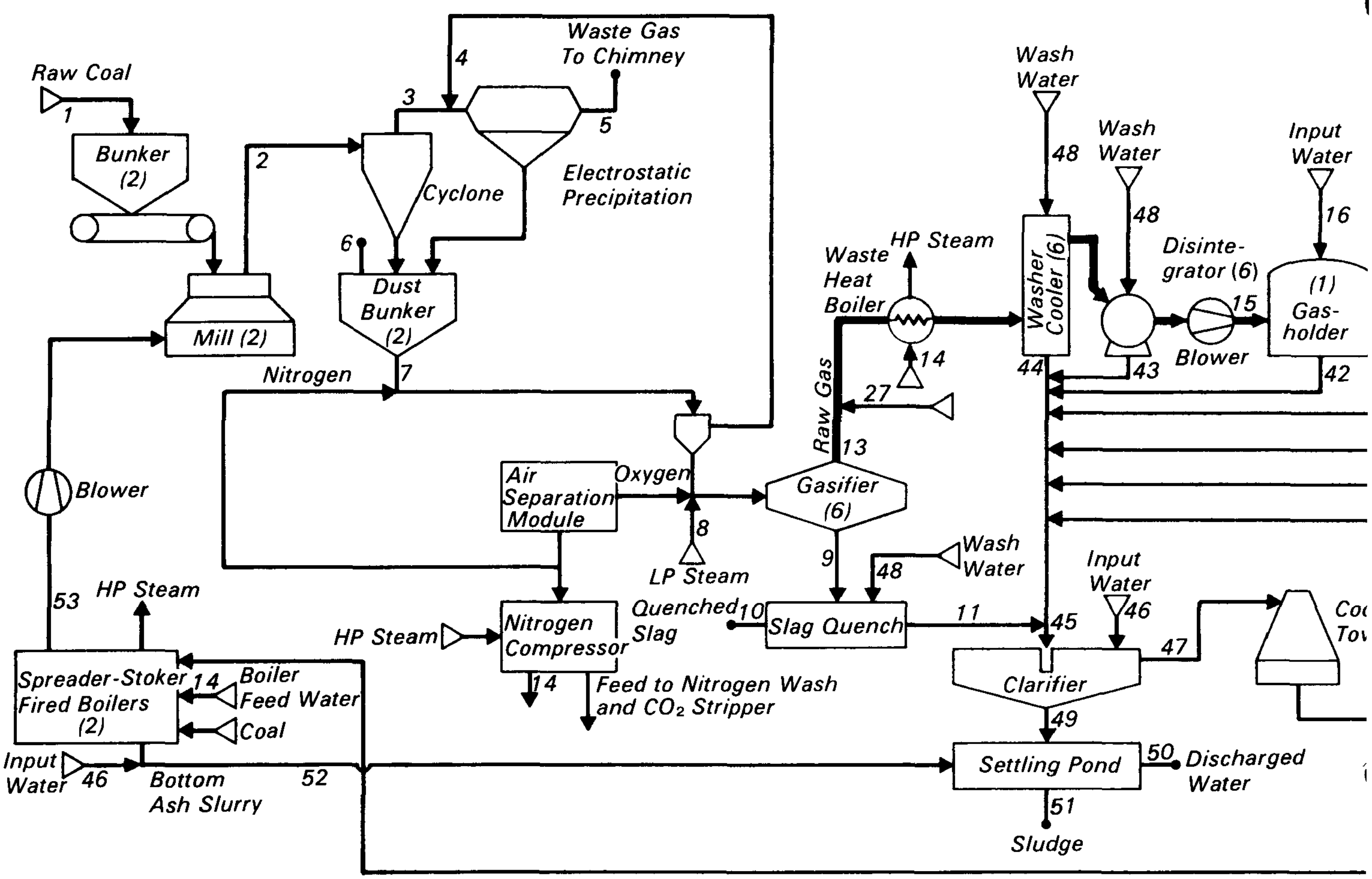
Several aqueous and solid waste streams were not tested in the initial program and data relating to their characteristics would be helpful in the evaluation of pollution control needs for U.S. facilities. Table 2 identifies these streams along with the type of data of interest for each. As indicated in the table, data are needed on the characteristics of aqueous streams resulting from raw gas cooling and particulate removal, from slag quenching and from the cold water wash unit (HCN removal). Of major concern are constituents in the aqueous streams (e.g., NH_3, HCN, H_3N) which may become volatilized in the clarifier or cooling tower systems, and result in atmospheric discharges. In addition, characteristics of the gas quenching wastewaters would indicate the original crude gas composition, which would be helpful in evaluation of potential wastes generated by K-T designs featuring other gas cooling/particulate removal systems. To complete constituent mass balances around the gasifier/gas cooling systems, repeat sampling of the raw gas (after the blower) would be desirable so that a consistent set of data is available.

Also indicated in Table 2 are solid wastes/sludges generated by the slag quenching operation and by the clarifier unit. The primary concern with these wastes is the leachability of specific trace elements and other potentially toxic substances. The leach test referred to in the table is that specified in regulations promulgated by the EPA under the Resource Conservation and Recovery Act of 1976 (RCRA). The RCRA regulations are currently being revised; the revision may result in changing the leach test procedures. This type of data would be used to indicate the disposal requirements/methods for solid wastes generated by facilities built in the U.S.

Note that additional sampling/testing activities at the Modderfontein facility would have as the primary goal that of providing basic characterization data on K-T generated wastes so that control technology requirements for facilities built in the U S. can be identified early in the planning stages. It is not intended that any data resulting from tests at Modderfontein be used for the purpose of either promoting or criticizing specific process designs or operating practices of that facility, which was designed in 1972 and which met the local environmental regulations in force at that time

References

1. IERL-RTP Procedures Manual: Level 1 Environmental Assessment (Second Edition), EPA-600/7-78-201 (NTIS PB 293 795), October 1978.
2. Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, EPA/EMSL, Cincinnati, OH, Revised April 1977.
3. EPA/IERL-RTP Procedures for Level 2 Sampling and Analysis of Organic Materials, EPA-600/7-79-033 (NTIS PB 293 800), February 1979.
4. SAM/IA: A Rapid Screening Method for Environmental Assessment of Fossil Energy Process Effluents, EPA-600/7-78-015 (NTIS PB 277 088), February 1978.
5. Multimedia Environmental Goals for Environmental Assessment,



1 Raw coal
2 Dry, milled coal
3 Coal fines
4 Recycled coal conveying gas
5 Waste gas
6 Purge gas
7 Coal dust
8 Low pressure steam from gasifier water jacket
9 Hot slag
10 Quenched Gasifier slag
11 Slag quenching waste water
12 [unassigned]
13 Raw gas
14 Steam condensate/ recycled boiler feed water
15 Raw gas after blower
16 Input water [CW]
17 Compressed raw gas
18 HCN free raw gas
19 Sulfur free product gas
20 Compressed sulfur free gas
21 Shifted product gas
22 CO_2 free product gas
23 NH_3 synthesis feed gas
24 NH_3 synthesis feed [compressed]
25 Recycle gas
26 Spent catalyst
27 Purge water
28 Nitrogen wash tail gas
29 Methanol
30 Recycle methanol
31 CO_2 rich methanol
32 Diluted rectisol condensate
33 Tail gas
34 CO_2 rich acid gas
35 H_2 rich acid gas
36 H_2 rich methanol
37 H_2 rich methanol
38 Tail gas
39 HCN wash condensate
40 Compressors condensate
41 Electrostatic precipitator wash water
42 Water seal waste water
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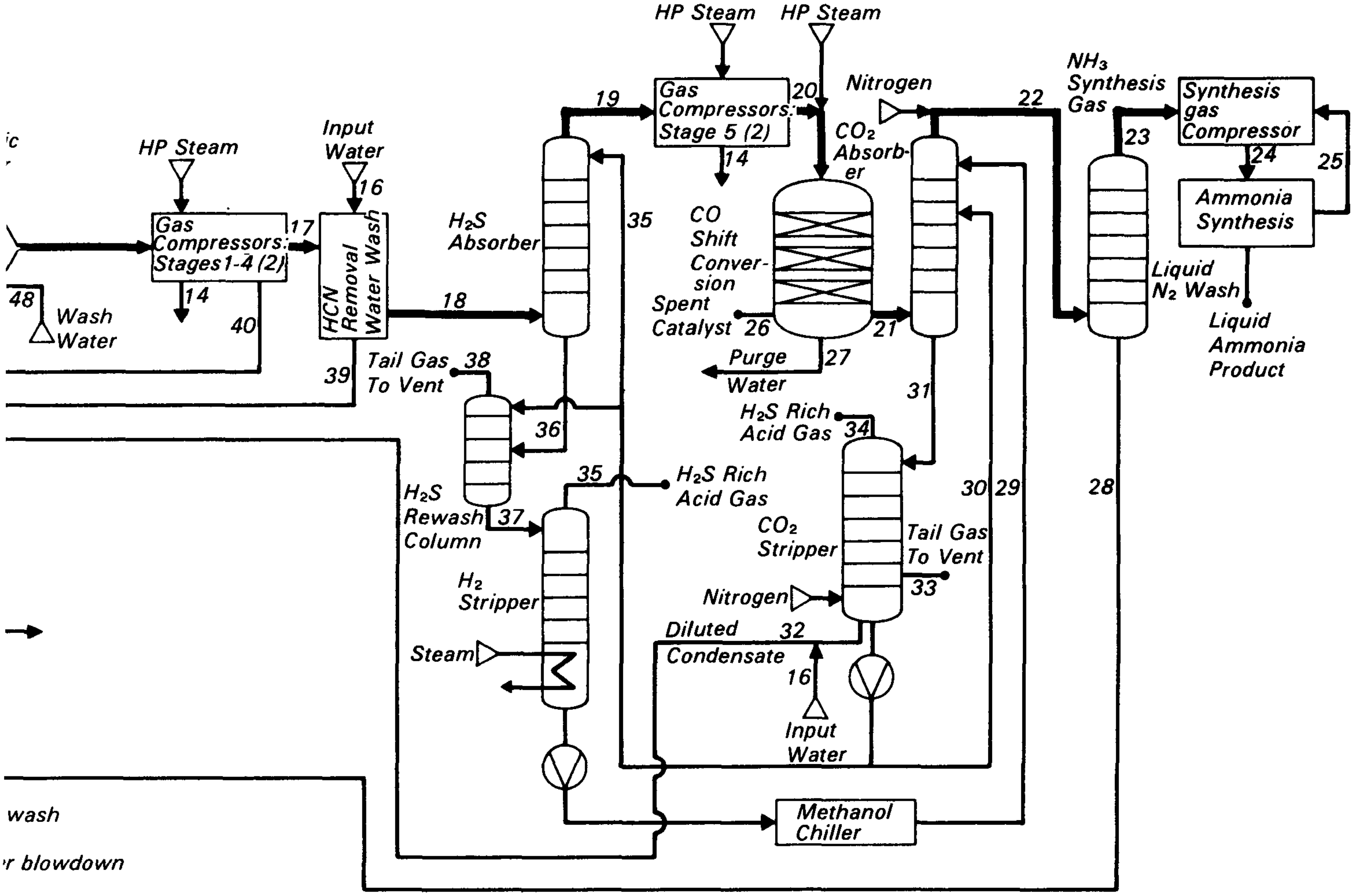
Figure 1. *Schematic of Modderfontein Koppers-Totzek Coal Gasification Facility.*

Volumes I-IV, EPA-600/7-77-136a/b (NTIS PB 276 919 and PB 276 920), November 1977, and EPA-600/7-79-176a/b (NTIS PB 80-115 108 and PB 80-115 116), August 1979.

6. Environmental Assessment: Source Test and Evaluation Report—Chapman Low-Btu Gasification, EPA-600/7-78-202 (NTIS PB 289 940), October 1978.

7. Environmental Assessment: Source Test and Evaluation Report—Wellman-Galusha (Glen Gery) Low Btu Gasification, EPA-600/7-79-185 (NTIS PB 80-102 551), August 1979.



ic

wash

r blowdown

PSE]
ent
h/water
er solids
discharge

sludge
lurry
ry coal

Table 2. *Additional Data Needs for Koppers-Totzek Process*

Stream Name	Stream No.**	Constituents/Parameters of Interest	Uses of/Justification for Additional Data
Coal Feed to Gasifier	7	Proximate/Ultimate, Trace elemental survey.	To corroborate data collected from initial STE.
Input Water (Purified Sewage Effluent)	46	Standard wastewater tests*, Trace element survey, Organic compounds survey, priority pollutants, level 2 as needed (POM's).	To corroborate data collected from initial STE and to provide background comparisons for the aqueous process streams.†
Input Water (Cooling Water)	16	Standard wastewater tests*, Trace element survey, Organic compounds survey, priority pollutants, Level 2 as needed (POM's).	To corroborate data collected from initial STE and to provide background comparisons for the aqueous process streams.†
Washer Cooler Blowdown	44	Standard wastewater tests*, Trace element survey, Organic compounds survey, Level 2 as needed (POM's).	To indicate those constituents of crude K-T gas which are likely to be removed/condensed with water in this or alternate quench designs.†
Disintegrator Blowdown	43	Standard wastewater tests*, Trace element survey, Organic compounds survey, Level 2 as needed (POM's).	Same as for Washer Cooler Blowdown.†
ESP Wash Water	41	Standard wastewater tests*, Trace element survey, Organic compounds survey, Level 2 as needed (POM's).	Same as for Washer Cooler Blowdown.†
Raw Gas Compressors Condensate	40	Standard wastewater tests*, Trace element survey, Organic compounds survey, Level 2 as needed (POM's).	To corroborate data collected from initial STE and to allow constituent material balances around gasification operations.†
HCN Removal Wash	39	Standard wastewater tests*, Trace element survey, Organic compounds survey, Level 2 as needed (POM's).	To allow constituent material balances around gasification operations.†
Slag Quench Blowdown	11	Standard wastewater tests*, Trace element survey, Organic compounds survey, Level 2 as needed (POM'S).	To indicate solids buildup and consequent blowdown requirements in the slag cooling circuit and to allow constituent material balances around gasification operations.†
Clarifier Influent	45	Standard wastewater tests*, Trace element survey, Organic compounds survey, priority pollutants, Level 2 as needed (POM's).	To allow constituent material balances around gasification operations.†
Clarifier Effluent	47	Standard wastewater tests*, Trace element survey, Organic compounds survey, priority pollutants, Level 2 as needed (POM's).	To compare with clarifier influent in order to indicate degree of removal of both dissolved and suspended materials expected during clarification and the possible atmospheric emissions of volatile substances.†
Cooling Tower Recycle Water	48	Standard wastewater tests*, Trace element survey, Organic compound survey, priority pollutants, Level 2 as needed (POM's).	To indicate possible atmospheric emissions of volatile substances in clarifier effluent and to allow constituent material balances.
Quenched Gasifier Slag	10	RCRA leach test for soluble elements/substances which may be potentially toxic (POM's).	To indicate the likely disposal requirements for K-T solid wastes for facilities constructed in the U.S. and to be able to relate data to U.S. coals.†
Settled Clarifier Solids/Clarifier Underflow	49	RCRA leach test for soluble elements/substances which may be potentially toxic (POM's).	To indicate the likely disposal requirements for K-T solid wastes for facilities constructed in the U.S.†
Raw Gas after Blower	15	Flow rate, temperature, H_2, CO, CO_2, H_2S, COS, CS_2, mercaptans, NH_3, HCN, methane, higher hydrocarbons, POM's, particulate matter, H_2O.	To corroborate initial STE data and to allow constituent material balances around gasification operations.
Raw Gas prior to Acid Gas Cleanup and Shift	18	Flow rate, temperature, H_2, CO, CO_2, H_2S, COS, CS_2, mercaptans, NH_3, HCN methane, higher hydrocarbons, POM's, particulate matter, H_2O.	To allow constituent material balances around gasification operations.

* Standard wastewater tests include: Flow rate, temperature, hardness, conductivity, dissolved oxygen, pH, alkalinity, total suspended solids, total dissolved solids, BOD, COD, TOC, NH_3, SCN^-, CN^-, Cl^-, sulfur species, phosphorus species.

† Bioassay Tests. The future data base may have to include bioassay data to fully determine the requirements for meeting U.S. environmental standards. Such tests would focus on final discharges (such as stream 10, above) and any final aqueous effluents. However bioassay tests on selected in-process streams would have value because the resultant larger data base would aid in correlating biological toxicity with chemical composition.

**Stream numbers correspond to those shown in Figure 1.

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The complete report, entitled "Environmental Assessment: Source Test and Evaluation Report, Koppers-Totzek Process," (Order No. PB 81-185 613; Cost: $9.50, subject to change) will be available only from:
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