CONTROL TECHNOLOGY DEVELOPMENT FOR FUEL CONVERSION SYSTEM WASTES

Louis E. Bostwick
Pullman Kellogg
a Division of Pullman Incorporated
Houston, Texas

Abstract

Pullman Kellogg's contract with the Environmental Protection Agency concerns control technology development for fuel conversion system waste utilization and disposal, for coal storage, preparation, and feeding, and for wastewater treatment. The program includes assessment of available and developing control technology as applied to fuel conversion effluents/emissions/wastes and relationship to present and proposed environmental regulations, continues with theoretical and experimental development of promising alternate control technologies, then concludes with an overall comparative analysis of all technologies and an engineering design and cost estimate for those control methods judged to be appropriate for integration into conversion system flow schemes.

Since the program has been operating for only five of its scheduled 36 months, this paper may be considered as a progress and planning report.

Pullman Kellogg's contract with EPA has as its objective the development of control technology for fuel conversion system waste utilization and disposal, for coal storage, preparation, and feeding, and for wastewater treatment. The 36-month project involves assessment of available and developing control technology, development of control technology and evaluation of control technology. The work is designed to interface with other studies in the EPA synthetic fuels program for interchange of information and definition of problems.

THE PROJECT PROGRAM

The program began in April 1977 with literature searches and data surveys directed toward definition of the emission streams in fuel conversion processes by quantity and composition, assessment of available and developing control technology and identification of existing and proposed environmental requirements. The results of these efforts are the base for the steps of the program that follow:

1. *Projection of new or more stringent environmental standards.*
   Hazardous or environmentally dangerous constituents of conversion plant waste streams are evaluated and new or more stringent regulations are projected with emphasis on health effects, land use considerations and geography. These criteria serve as guides for development of control technology.
2. *Identification of control needs.*
   Controls required to meet existing and proposed standards and criteria for conversion processes are determined by comparison of the pollutant standard with effluents from available or developing control processes. Areas requiring better control technology are then defined.
3. *Identification of new data needs.*
   Comparison of the review of control technology with the identification of control needs defines the areas in which data are insufficient or unavailable for assessment of needs for available technology or control methods.
4. *Field data acquisition.*
   Data to at least partially fill the gaps defined as new data needs are gathered during field trips to observe control processes in fuel conversion processes or in similar control processes in other industries. Compositions and quantities of emissions streams are determined and sampling and analysis of control process influent and effluent streams are accomplished.
5. *Economic analysis of available and developing control technology.*
   Capital and operating costs for individual control processes are determined and then used to predict costs for environmental control for fuel conversion processes.

6. *Program emphasis for development of control technology.*
In accordance with the overall EPA objectives, a multiyear control technology development plan is formulated, time-phased to coincide with fuel conversion technology development.
7. *Evaluation of alternate control technology.*
Theoretical studies of control technology that are available in the literature are reviewed for mechanisms that show promise and might be developed for areas where new technology is needed. Assembly of conceptual flow diagrams of promising control routes is followed by cost evaluations and comparison of proposed processes with existing processes. With consideration of the program emphasis philosophy, the field of new processes is narrowed to those most attractive, technically and economically, for further development.
8. *Laboratory and bench-scale development.*
Accurate definition of objectives and analysis of means of attaining the objectives leads to formulation of a program for experimentation to establish conditions of operations required to achieve the desired level of control. The laboratory work is seen as a screening mechanism to establish the range of control process operations which aids in selection of operating methods for bench-scale development.
9. *Integration of process with needed control technology.*
This check point ensures that processes under development in the laboratory fit the specific situations they are intended to control. New laboratory data are compared with the concepts developed during evaluation of promising alternate technology.
10. *Overall comparative analysis of control processes.*
Existing available control processes, as required by fuel conversion processes, are compared according to costs, level of control, applicability and other advantages and disadvantages. After laboratory and bench work are complete, promising developing control technology is evaluated by the same criteria and with such additional considerations as costs of remaining development programs and risks.
11. *Design preparation.*
Several control processes are selected from the results of the overall comparative analysis and capital investment and operating costs are developed for each complete control process.

PROGRESS IN THE PROGRAM

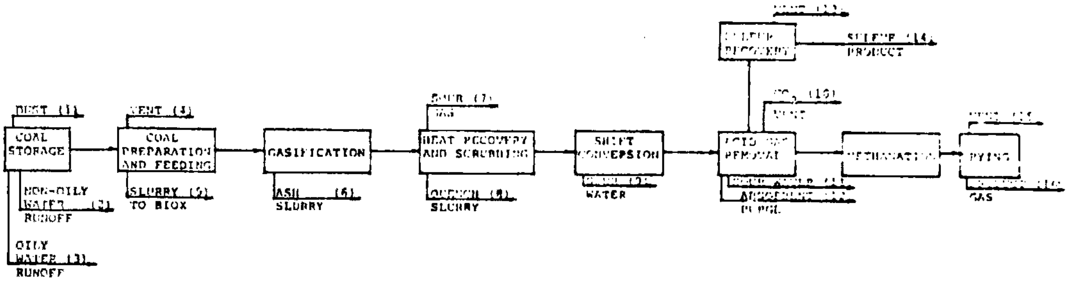
Literature Search for Conversion Process Information

As originally conceived, information on the quantities and compositions of the effluents and wastes from each coal conversion process would be collected and grouped as solid, liquid, or gas in order to define the areas for application of control technology. However, a lack of useable information on conversion process emissions became apparent very early in the survey of published reports and articles concerning the processes because the emphasis in development of conversion processes had been almost entirely on the processes themselves and much less attention had been given to collecting data on their emissions. Some small amount of information was published on emissions, derived mainly from laboratory and bench-scale process development work, and some information was available in reports on conceptual conversion process designs, but the total was insufficient for definition of required control technology. The problem was compounded by the one- to two-year time interval between completion of a report of work on a particular process and its publication and procurement.

Literature searches were conducted through EPA, NTIS, and Chemical Abstracts data banks and the microfiche library of Oak Ridge National Laboratory reports at Rice University in Houston. The search continues through weekly monitoring of NTIS abstracts and Chemical Abstracts for the life of the project.

TABLE 1

AVAILABLE INFORMATION ON EMISSIONS FROM COAL GASIFICATION PROCESSES

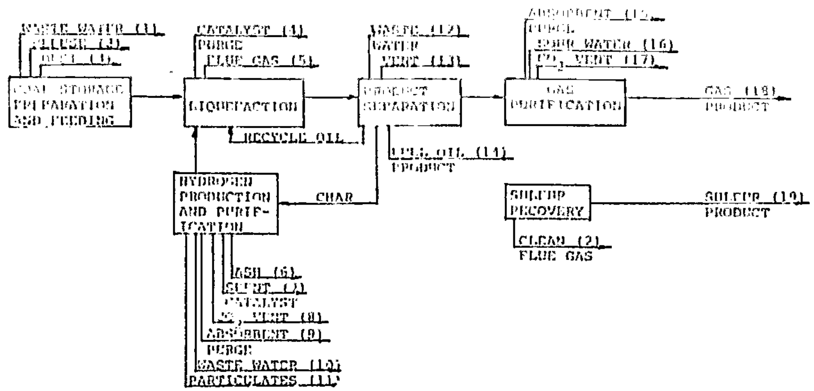


	Stream Analyses (1)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CO_2 Acceptor					P	A	A	A			A				A	A
Synthane				A	P	A		A	A						A	
HyGas (Steam/Ox.)						P		A	A	Q			Q		A	A
HyGas (Steam/Iron)				A	A	P		P	A		A		Q		A	A
Lurgi (Dry Ash)					P	P	A	A		Q			Q		Q	A
Lurgi (Slag Ash) (2)																
Bi-Gas						P		P	P				P	P	P	P
Battelle Agglomerating Ash (3)																
COGAS (4)																
Hydrane						A										A
Koppers-Totzek						A		A								A
Winkler				A		P										A
Westinghouse (15)																
Foster Wheeler (6)																
AI Molten Salt (7)																A
Combustion Engineering (8)						Q										Q
Riley-Morgan						P			P							A
Wellman-Galusha									P							A
U-Gas				Q		A			Q				Q			A
Babcock & Wilcox (9)				A				A				A	A			
ERDA/MERC (10)																
Texaco (2)																
BCR (11)																
Woodall-Duckham (12)																

(1) A = Analysis, either real or conceptual; P = Partial analysis; Q = Quantities only.
(2) Proprietary. No data released to date. Possible future release.
(3) PDU operation expected late 1977. Effluent data available possibly in early 1978.
(4) Development mostly proprietary, very little effluent data. Now being evaluated by ERDA vs. Slagging Lurgi.
(5) Emphasizes turbine development. Little effluent data available.
(6) Conceptual design only. No data. Used Bi-Gas gasifier.
(7) PDU scheduled for 1978-9 operation. Very limited data mostly on process.
(8) Pilot plant effluent data expected in six-twelve months.
(9) Will not be built. Bi-Gas is very similar and was built by B&W.
(10) Process development with no published effluent data.
(11) Pilot Plant. No effluent data.
(12) Commercial operation. No published effluent data.

TABLE 2

AVAILABLE INFORMATION ON EMISSIONS FROM COAL LIQUEFACTION PROCESSES



	Stream Analyses (1)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COED (2)	P	Q				P		Q		A		A		Q		A			Q	A
Clean Coke (3)																		Q		
SRC (4)			Q			Q								P			A	P	Q	A
H-Coal (5)				Q								Q		P				Q	Q	
Synthoil (6)						A						Q		A				Q	Q	
Donor Solvent (7)																				

(1) A = Analysis, either real or conceptual; P = Partial analysis; Q = Quantities only.
(2) Information from conceptual design for COED combined with COGAS.
(3) No published effluent information to date. Data expected by end of 1977.
(4) Information from conceptual design of SRC II process.
(5) Pilot plant construction to be completed in 1978, operation scheduled into 1980.
(6) PDU operation to start in 1978.
(7) No published effluent information to date. Environmental Assessment scheduled for late 1977 completion.

Results of the Literature Search for Conversion Process Information

The literature searches were supplemented by direct contact with conversion process developers or with ERDA, whichever was applicable, to ascertain process status and availability of reports that would contain emissions data. The results of the data search are summarized in Table 1 for gasification processes and Table 2 for liquefaction processes. The data gaps, the status of the processes and the projections for process development in the future emphasize the validity of one of the basic concepts of the Fuel Process Branch of EPA: that the level of environmental concern may be relatively low during the initial investigations of promising fuel conversion processes and should increase to comprehensive programs as the conversion processes are developed during the pilot plant and larger operations. Thus, lack of published emissions data on a relatively new, bench-scale process is understandable and is not a cause of great concern for the moment. Lack of any plans for gathering emissions data from a process, or lack of access to any data that may be reported, are both causes for concern from the standpoints of being aware of progress of development of the conversion process and of outlining for special attention any unusual emissions problems. For these reasons, efforts in monitoring literature and in maintaining contacts with process developers are planned as a continuous update of emissions information through the project.

Gasification Process Categorization

The premise that conversion processes fed with the same coal and operating under the same or similar conditions will have the same or similar emissions has been applied to the coal gasification processes. The groupings that result allow application of emissions information among processes within each group in order to close the information gaps.

Coal gasification processes were divided into "clean" processes, in which little or no oils, tars, and phenols are produced, and "dirty" processes that produce oils, tars, and phenols. The effect of the grouping on the availability of data within the group is shown in Table 3.

Classifying gasification processes according to their production of oils, tars, and phenols is useful because these components eventually appear in the waste water streams. Their presence requires the use of additional treatment units (for example, biological oxidation or phenol recovery) while their absence means significantly less intense water treatment will be needed. In addition, production of these contaminants generally reflects gasifier operating conditions, which in turn determine the form of solid waste produced (slag or dry ash).

TABLE 3

CATEGORIZATION OF COAL GASIFICATION PROCESSES

Clean Processes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CO_2 Acceptor					P	A	A	A			A				A	A
Bi-Gas						P		P	P				P	P	P	P
Koppers-Totzek						A		A								A
Winkler				A		P										A
Westinghouse																
Foster Wheeler																
Combustion Engineering						Q										Q
U-Gas				Q		A			Q				Q			A
Babcock & Wilcox				A				A				A	A			
CONSENSUS				A	P	A	A	A	P		A	A	A	P	A	A
Dirty Processes																
Synthane				A	P	A		A	A						A	
HyGas (Steam/Ox.)						P		A	A				Q		A	A
HyGas (Steam/Iron)				A	A	P		P	A		A		Q		A	A
Lurgi (Dry Ash)					P	P	A	A		Q			Q		Q	A
Lurgi (Slag Ash)																
Battelle Agglomerating Ash						P		P	P				P	P	P	P
COGAS																
Hydrane						A										A
Riley Morgan						P			P							A
Wellman-Galusha									P							A
CONSENSUS				A	A	A	A	A	A	Q	A		P	P	A	A

*A = Analyses, either real or conceptual; P = Partial analysis; Q = Quantities only.

Oils, tars, and phenols may be formed during the gasification of coal. However, by increasing the gasifier temperature, the residence time or the average bed temperature (by operating in the entrained flow mode or injecting the coal feed into the hot bottom part of the gasifier), production of oils, tars, and phenols is reduced or eliminated.

It is noteworthy that the "clean" processes have either entrained-flow or fluidized-bed gasifiers operating at temperatures of 1900° F or higher and produce ash as a slag or as agglomerates. In contrast, the "dirty" processes have either fixed bed or fluidized-bed gasifiers operating at temperatures below 1900° F.

There are several exceptions to the generalization. The CO_2 Acceptor gasifier operates at less than 1900° F but is "clean" because the gasifier design provides for long residence time. The Winkler gasifier also operates at less than 1900° F but is "clean" because the feed coal is injected into the bottom of the gasifier to yield a higher average bed temperature. Not much is known at this time concerning the Battelle Agglomerating Ash Process, however, sources indicate that no tars or oils are produced but that some heavy inorganics may be present.[1] The Al Molten Salt Process is a special case in that no oils, tars, or phenols are produced, but the reaction system may produce effluents significantly different from the other gasification processes.

From the consensus of each of the process groups a first approximation of the quantities and concentrations of emission streams may be deduced. Used with caution, the deductions will serve as a basis for evaluation of the efficiency of the application of available and developing control technology to the pollutants by comparison with existing and proposed environmental standards and criteria for emissions from conversion plants.

The weaknesses in the categorization method for deduction of emission stream quantities and compositions are apparent. Strengthening of the information is needed to make as firm as practicable the foundation for the subsequent steps of the program. Therefore, plans have been formulated for monitoring literature and implementing personal contacts to gather and correlate data as developed on the processes that are developing rapidly and that offer the most promise for generating useable effluent data:

- CO_2 Acceptor (Clean, High-Btu)
- Koppers-Totzek and/or Winkler (Clean, Low, or Medium-Btu)
- Synthane, Lurgi and HyGas (Dirty, High-Btu)
- Riley-Morgan and Wellman-Galusha (Dirty, Low-Btu)

Liquefaction Process Categorization

Grouping of coal liquefaction processes according to operating conditions in order to deduce the composition and quantity of each emission stream was not as successful as with coal gasification processes due to lack of meaningful data. As a first approximation, the processes were separated into two groups:

	Process	Temperature	Pressure	Phase*
Group 1: Pyrolysis/Hydrocarbonization				
	COED	550-1500°F	8 psig	S,G
	Clean Coke	880-900	150	S,G
Group 2: Solvent Hydrogenation				
	SRC	800-900°F	1500	L,S,G
	H-Coal	850	2000-4000	L,S,G
	Donor Solvent	700-900	1450-2450	L,S
	Synthoil	850	2000-4000	L,S,G

*L = Liquid; S = Solid; G = Gas

In general, coal liquefaction processes are more nearly alike than are coal gasification processes. For example, since all liquefaction processes produce hydrocarbon liquids, it is inevitable that there will be effluent streams containing tars, phenols, and oils and that these streams will require effluent control systems similar to those applicable to the fixed bed ("dirty") gasification processes.

Hydrogen for coal liquefaction can be generated either by light hydrocarbon reform-

[1] It should be noted that "heavy inorganics" are present in *all* processes due volatility of such components in the coal, e.g., Cd, Zn, Cl, Hg, F, As, etc. Also nitrogen compounds in the coal will appear as ammonia and cyanides/cyanates in *all* processes.

ing or by gasification of residue/char. The general statement may be made that hydrogen production by similar methods yields similar effluents and requires similar control methods for that process step.

In Group 1, the byproduct char from the COED process is gasified to produce hydrogen and fuel gas. Studies on the gasification of the char have led to the development of the COGAS process, and COGAS now includes COED. The Clean Coke process produces a coke substitute from the byproduct char. Both processes use low-pressure staged fluid bed reactors to pyrolyze/hydrocarbonize coal into char and oil.

The processes in Group 2 liquefy coal by combining it with a recycle oil stream to form a slurry, adding hydrogen and heating the mixture at high pressure to yield oil and a residue of undissolved coal and ash. SRC does not use a catalyst. Donor Solvent catalytically hydrogenates the recycle solvent. H-Coal and Synthoil use a catalyst in the liquefaction reactor. The residue may be disposed of by combustion, coking or gasification.

An attempt to utilize the effect of the grouping on the availability of data within the group is ineffective, due to the lack of data in many areas and the lack of definition of the means of disposal of residue. Monitoring literature and implementation of personal contacts in order to gather and correlate information as it is developed are recognized as being of paramount importance and are being vigorously pursued.

Compilation of Existing and Proposed Environmental Requirements

Environmental regulations, standards, and related restrictions have been collected, organized, reviewed, and synopsized. Sources were State, regional, and Federal publications and, wherever applicable, international agreements. Detailed evaluation was limited to those constituents of effluent, emission, and waste streams which best judgment indicated will be hazardous or environmentally dangerous due to inherent properties or to concentrations. The Multimedia Environmental Goals that are currently under development by IERL-RTP are included in the evaluation, since these establish a concentration for each constituent which estimates a level of concern for assessment purposes.

The draft report of the compilation and evaluation of the environmental requirements is scheduled for completion by the end of September. Monitoring of source material will be a continuing effort through the project.