SECTION 3. SURVEY AND REVIEW OF CURRENT GASIFICATION TECHNOLOGY AND PRACTICE

The data and information collected during the review of the current "state of the art" include material obtained from the literature, through field interviews, and developed on the project.

A. Literature Search

A search of the literature pertinent to coal gasification research and development was made with emphasis being placed on the literature which has appeared since the publication of the excellent review of coal gasification by C. G. von Fredersdorff and M. A. Elliott.(1)

The purpose of the literature search was to compile a permanent record and to make available the published information in the following areas:

1. Current gasification practice and technology
2. Areas of gasification research which have been or are being investigated
3. Economic data related to various processes

1. Library Procedure: The literature was and still is being read, abstracted, and indexed as part of a continuing activity of the overall program. Whenever possible, copies of documents are obtained and placed in a permanent file where they are readily available for reference.

Index cards being prepared for filing contain the following information:

1. File number
2. Key phrases for subject identification
3. Authors' names and business affiliations
4. Title
5. Source
6. Brief abstract

The basic subject index which will be expanded as work progresses is based on the BCR library subject index. The assigned category number for gasification is 530. The following basic subject breakdown is used:

530.000	Gasification - General
530.100	Gasification - Theoretical
530.200	Characteristics and reactions of gases
531.000	Gasification processes
531.100	Atmospheric pressure
531.200	Elevated pressure
531.300	Underground gasification

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(1) von Fredersdorff, C. G. and Elliott, M. A., "Chemistry of Coal Utilization, Supplementary Volume," Lowry, H. H., ed., New York: John Wiley and Sons, Inc., 1963. pp 892-1022.

532.000	Gasification auxiliaries
532.100	Coal preparation
532.200	Oxygen production
532.300	Gas purification
532.400	Tar separation
532.500	Methane synthesis
532.600	Offsite facilities
532.700	Hydrogen production
532.800	Auxiliary equipment
532.900	Instrumentation
533.000	Gasification - Economics
534.000	Production of liquid fuel
535.000	Hydrogenation
536.000	Carbonization

2. Progress Achieved: The principal abstract journals have been examined for the period 1959 through 1964. They include the following:

Chemical Abstracts
Fuel Abstracts and Current Titles
Gas Abstracts
BCURA Monthly Bulletin, Abstract Section
Applied Science and Technology
Engineering Index

Where possible, articles referred to in these journals have been read and, when of sufficient value to the research group, copies have been obtained for ready reference in the library. Abstracts of some 250 papers form the basis for the annotated bibliography which is included as Appendix 3.1.

A large number of articles have been identified but have not been completely reviewed. Often the title gives sufficient indication of the material contained in an article; such items are included with this report as additional references; the author, title, and source of some 300 such papers are listed in Appendix 3.2. In many cases, some additional information about these papers is available to the project staff, however, final abstracts have not yet been prepared.

Many articles published prior to 1959 have been obtained and indexed for use by the project staff. These were selected on the basis of their direct application to areas of interest in relation to the processes being examined in depth. In most cases, they are already included in other collections of references and therefore, have not been included in either of the accompanying lists of references.

A substantial amount of work has been done in other countries and publication of this work has been in French, German, and Russian. Wherever possible, translations of these articles have been obtained from the U.S. Bureau of Mines,

the U.S. Office of Technical Services, the National Coal Board of England, the Commonwealth Scientific and Industrial Research Organization of Australia, and other reliable sources. French and German papers for which translations are not available have been read in the original. Two German papers of immediate interest to the project staff have been translated.(2) Copies of these translations are available from the BCR library at nominal cost of reproduction to interested parties.

B. Field Interviews

Field trips and field interviews with organizations in the United States and Europe were made to supplement and update information available from the published literature.

In the United States, the organizations included the United States Bureau of Mines, Illinois Institute of Gas Technology, and Battelle Memorial Institute, together with 10 industrial organizations; in England these included The Ministry of Power, The Gas Council, The Central Electricity Generating Board, The National Coal Board, together with the British Coal Utilisation Research Association and four industrial organizations; and in Germany, Bergbau-Forschung and nine industrial organizations. Also, seven additional contacts were made by mail with organizations in France, Netherlands, Austria, and England. The names and locations of the various organizations are listed in Appendix 3.3. Trip reports covering the visits with the various European organizations have appeared in the regular monthly progress reports. A summary of the European survey trip is given in Appendix 3.4.

C. Processes Reviewed

Data and information on all processes proposed for consideration were compiled for ready reference and future use. A summary of the processes considered is presented in Table 3-1. More complete information on these processes is included in Appendix 3.5.

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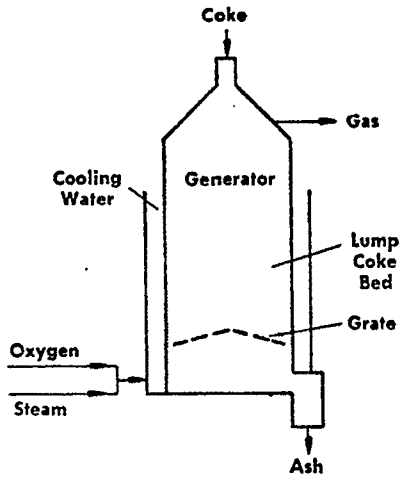
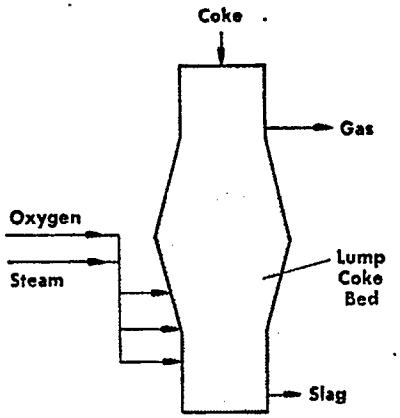
(2) Sabel, F., "Synthesis gas manufacture in a flame of free oxygen," Erdoel Kohle-Erdgas-Petrochemie 17 (8), 621-5 (1964).

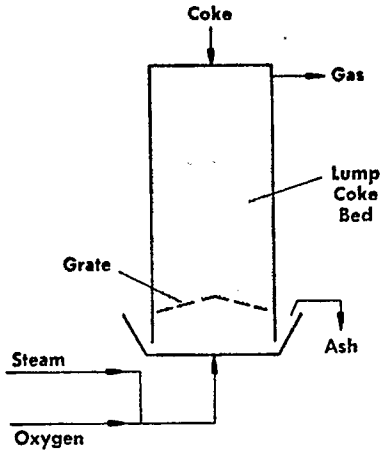
Danulat, F., "Interactions between gas and fuel in pressure gasification," Gas- Wasserfach 85, 557-62 (1942).



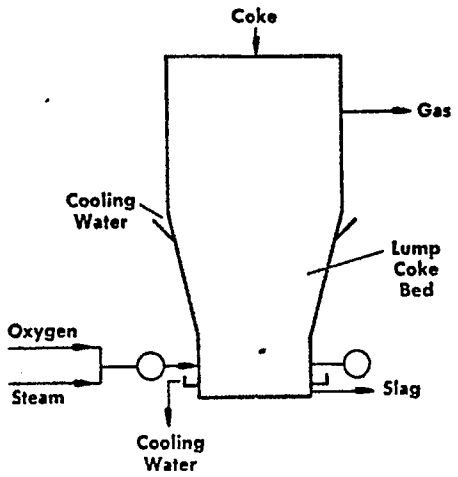
Process 1
CONVERTED UGI



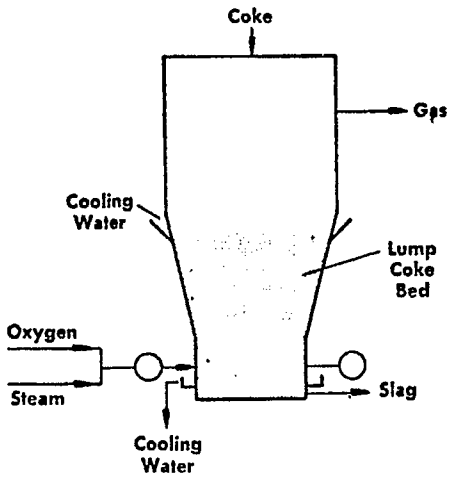
Process 2
THYSSEN GALOCZY



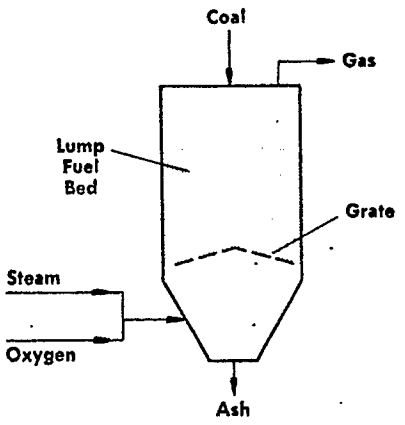
Process 3
KERPELY



Process 4
LEUNA SLAGGING



Process 5
LEUNA-BASF SLAGGING



Process 6
WELLMAN-GALUSHA

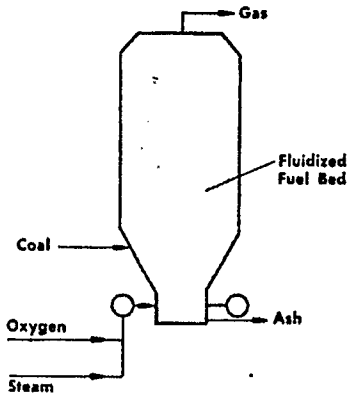
TABLE 3-1. SUMMARY OF AVAILABLE DATA ON COMMERCIAL AND PILOT-SCALE GASIFICATION PROCESSES

Process No.	I. Commercial Synthesis Gas Processes Using Oxygen and Coke	Contact Method	Pressure	Process Characteristics	Reactor Description	Reactor Diagram	Plant Description	Flow Diagram	Specific Performance	Material Balance	Heat Balance	Fuel Analysis	Gas Analysis	Reagent Cost
1	UGI Converted	Fx	A	S	S	S	N	N	S	S	I	I	I	S
2	Thyssen Galoczy	Fx	A	S	S	S	S	S	S	S	S	I	S	S
3	Kerpely	Fx	A	S	S	S	S	S	S	S	S	I	S	S
4	Leuna	Fx	A	S	S	S	N	N	S	S	I	I	S	S
5	BASF-Leuna	Fx	A	S	S	S	S	S	S	S	I	N	S	S
6	Wellman-Galusha	Fx	A	S	S	S	S	S	S	S	S	S	S	S

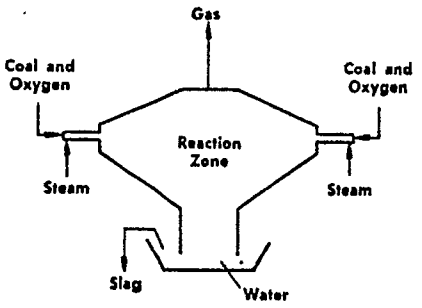
Fx = Fixed Bed
Fl = Fluidized Bed
En = Entrained

A = Atmospheric
E = Elevated

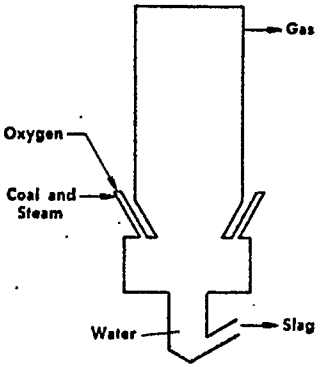
S = Data Satisfactory
I = Data Incomplete
N = No Data



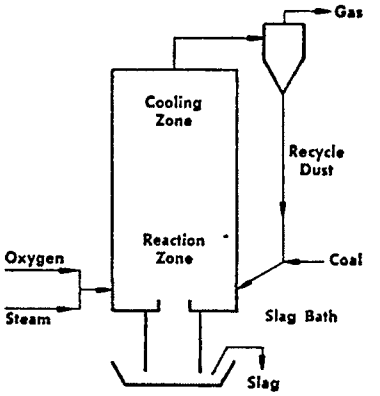
Process 7
BAMAG-WINKLER ATMOSPHERIC



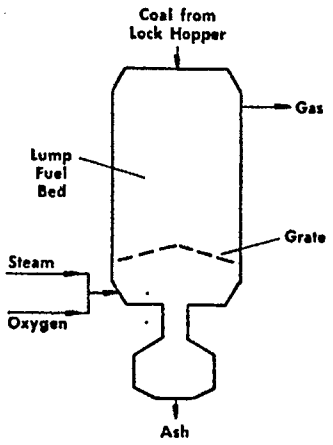
Process 8
KOPPERS-TOTZEK



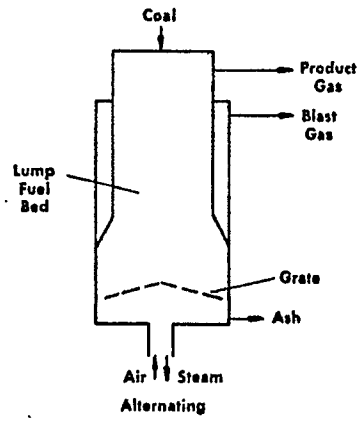
Process 9
B & W DuPONT



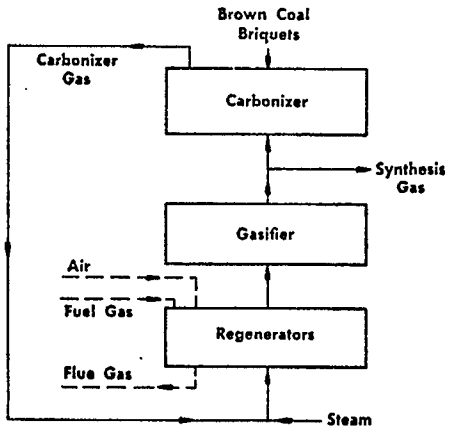
Process 10
RUMMEL SINGLE-SHAFT



Process 11
LURGI DRY-ASH



Process 12
GAS INTEGRALE



Process 13
PINTSCH HILLEBRAND

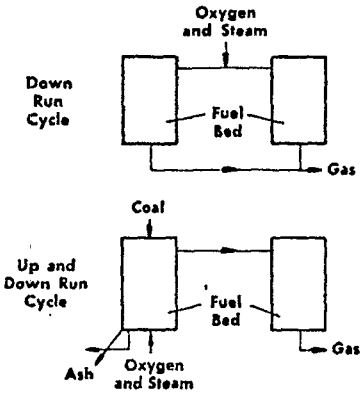
TABLE 3-1. SUMMARY OF AVAILABLE DATA ON COMMERCIAL AND PILOT-SCALE GASIFICATION PROCESSES (Continued)

Process No.	I. Commercial Synthesis Gas Processes Using Oxygen and Coal	Contact Method	Pressure	Process Characteristics	Reactor Description	Reactor Diagram	Plant Description	Flow Diagram	Specific Performance	Material Balance	Heat Balance	Fuel Analysis	Gas Analysis	Reagent Cost
7	Bamag-Winkler Atmospheric	Fl	A	S	S	S	S	S	S	S	S	S	S	S
8	Koppers-Totzek	En	A	S	S	S	S	S	S	S	S	S	S	S
9	B & W-DuPont	En	A	S	S	S	N	N	S	S	S	I	S	S
10	Rummel Single-shaft	En	A	S	S	S	S	S	S	S	S	I	S	S
11	Lurgi Dry-ash	Fx	E	S	S	S	S	S	S	S	I	I	S	S
	Using Air and Coal													
12	Gas Integrale	Fx	A	S	S	S	S	S	I	S	S	I	S	S
13	Pintsch Hillebrand	Fx	E	I	S	S	S	S	S	S	I	I	S	I

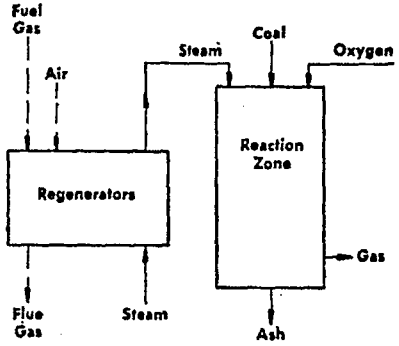
Fx = Fixed Bed
Fl = Fluidized Bed
En = Entrained

A = Atmospheric
E = Elevated

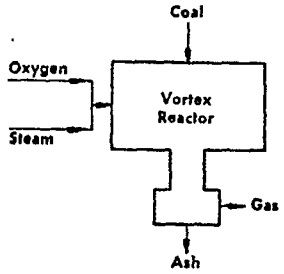
S = Data Satisfactory
I = Data Incomplete
N = No Data



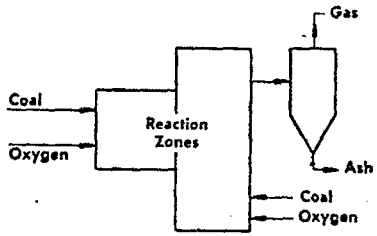
Process 14
BASF-FLESCH DEMAG



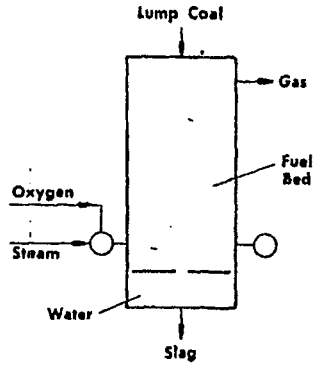
Process 15
PANINDCO



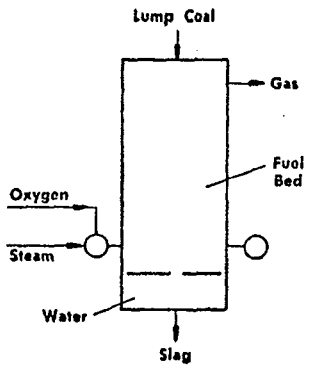
Process 16
USBM VORTEX



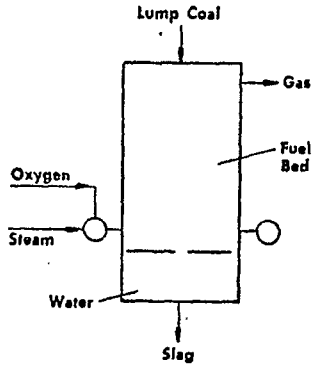
Process 17
INLAND STEEL



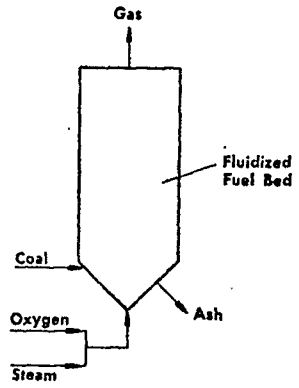
Process 18
GC-LURGI SLAGGING



Process 19
BCURA-LURGI SLAGGING



Process 20
USBM-LURGI SLAGGING



Process 21
HYDROCARBON RESEARCH

TABLE 3-1. SUMMARY OF AVAILABLE DATA ON COMMERCIAL AND PILOT-SCALE GASIFICATION PROCESSES (Continued)

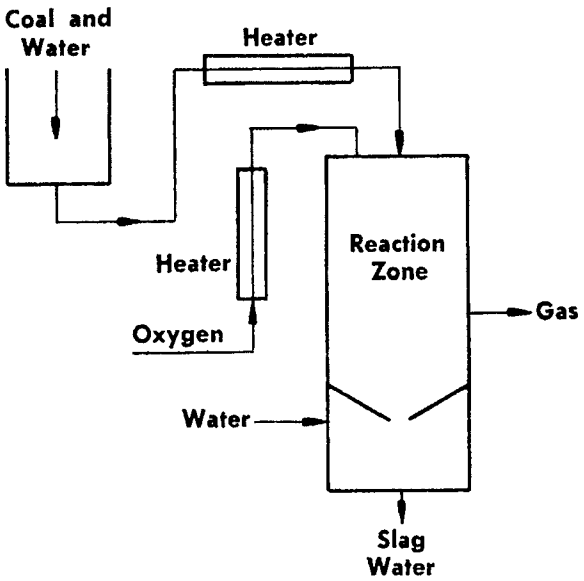
Process No.	II. Pilot-scale Synthesis Gas Processes Using Oxygen and Coal	Contact Method	Pressure	Process Characteristics	Reactor Description	Reactor Diagram	Plant Description	Flow Diagram	Specific Performance	Material Balance	Heat Balance	Fuel Analysis	Gas Analysis	Reagent Cost
14	BASF-Flesch-Demag	FxFl	A	S	S	S	N	N	S	S	S	I	S	S
15	Panindco	En	A	S	S	S	S	S						
16	USBM Vortex	En	A	S	S	S	S	S						
17	Inland Steel	En	A	S	S	S	N	N						
18	Gas Council-Lurgi	Fx	E	S	S	S	S	S						
19	BCURA-Lurgi*	Fx	E	S	S	S	S	S						
20	USBM-Lurgi	Fx		S	S	S	S	S						
21	Hydrocarbon Research	Fl	E	S	S	N	N	N	S	S	S	S	S	I

Fx = Fixed Bed
Fl = Fluidized Bed
En = Entrained

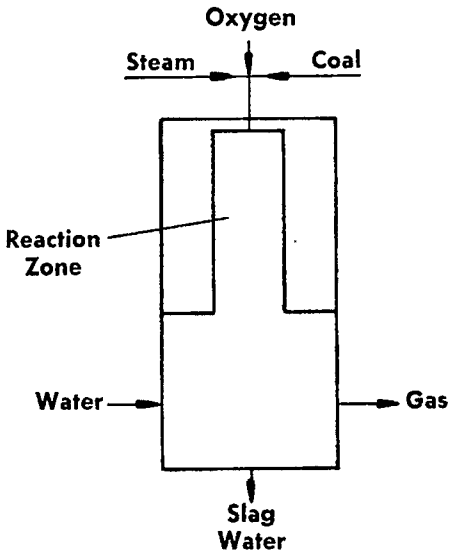
A = Atmospheric
E = Elevated

S = Data Satisfactory
I = Data Incomplete
N = No Data

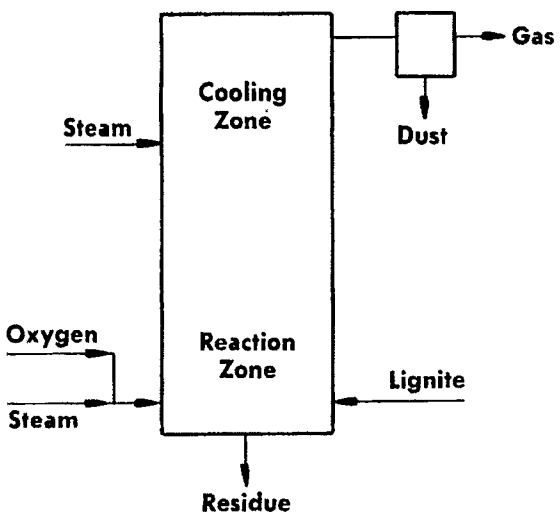
*Uses Coke



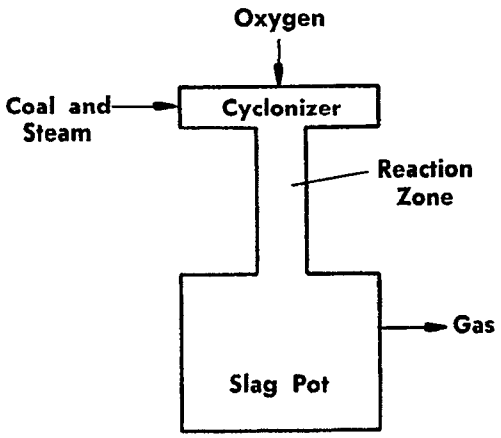
Process 22
TEXACO



Process 23
USBM MORGANTOWN



Process 24
BIANCHI



Process 25
IGT CYCLONIZER

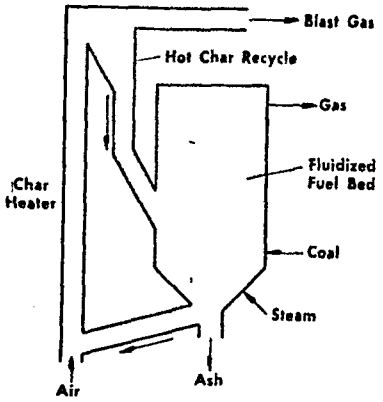
TABLE 3-1. SUMMARY OF AVAILABLE DATA ON COMMERCIAL AND PILOT-SCALE GASIFICATION PROCESSES (Continued)

Process No.	II. Pilot-scale Synthesis Gas Processes Using Oxygen and Coal	Contact Method	Pressure	Process Characteristics	Reactor Description	Reactor Diagram	Plant Description	Flow Diagram	Specific Performance	Material Balance	Heat Balance	Fuel Analysis	Gas Analysis	Reagent Cost
22	Texaco	En	E	I	I	N	I	S	I	S	S	S	S	I
23	USBM Morgantown	En	E	S	S	S	S	S						
24	Bianchi	En	E	S	S	S	N	N						
25	IGT Cyclonizer	En	E	S	S	S	S	S						

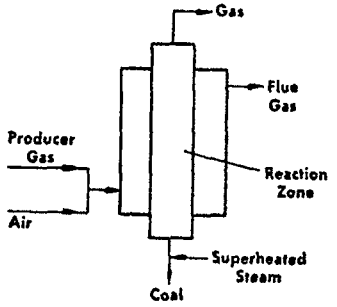
Fx = Fixed Bed
Fl = Fluidized Bed
En = Entrained

A = Atmospheric
E = Elevated

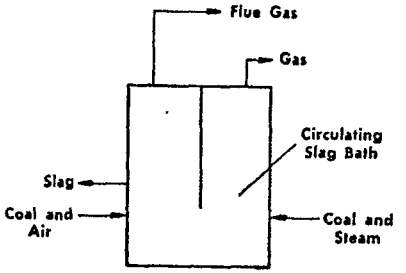
S = Data Satisfactory
I = Data Incomplete
N = No Data



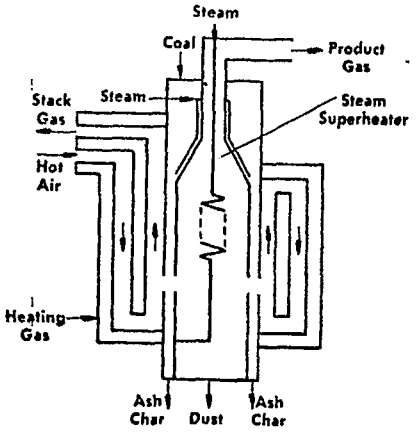
Process 26
ICI MOVING BURDEN



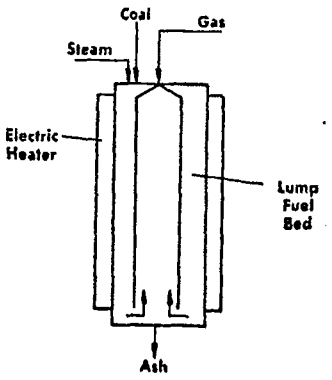
Process 27
HELLER PROCESS



Process 28
RUMMEL DOUBLE-SHAFT



Process 29
USBM ANNULAR RETORT



Process 30
USBM ELECTRICALLY HEATED

TABLE 3-1. SUMMARY OF AVAILABLE DATA ON COMMERCIAL AND PILOT-SCALE GASIFICATION PROCESSES (Continued)

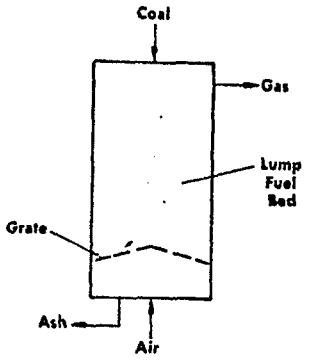
Process No.	II. Pilot-scale Synthesis Gas Processes Using Air and Coal	Contact Method	Pressure	Process Characteristics	Reactor Description	Reactor Diagram	Plant Description	Flow Diagram	Specific Performance	Material Balance	Heat Balance	Fuel Analysis	Gas Analysis	Reagent Cost
26	ICI Moving Burden	Fl	A	S	S	S	S	N						
27	Heller Process	En	A	S	S	N	N	N	S	S	S	S	S	S
28	Rummel Double-shaft	En	A	S	S	S	S	S						
29	USBM Annular Retort	Fx	A	S	S	S	S	S						
30	USBM Electrically Heated**	Fx	A	S	S	S	S	N						

Fx = Fixed Bed
Fl = Fluidized Bed
En = Entrained

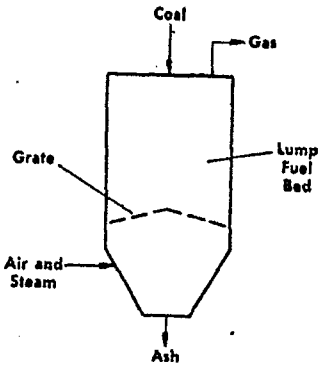
A = Atmospheric
E = Elevated

S = Data Satisfactory
I = Data Incomplete
N = No Data

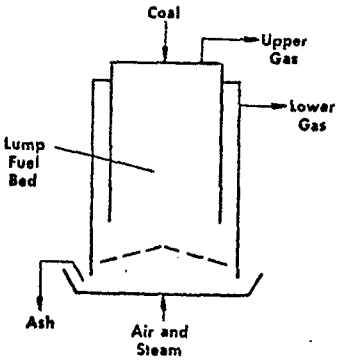
** Uses no air



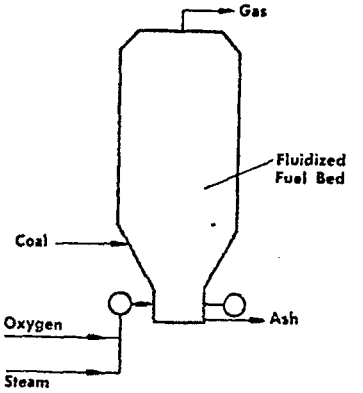
Process 31
POWER GAS MECHANICAL



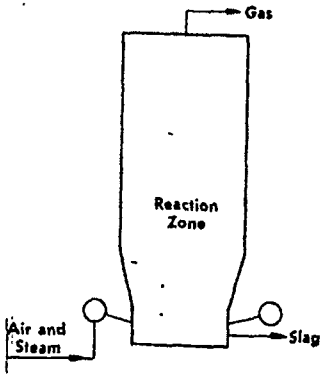
Process 32
WELLMAN-GALUSHA



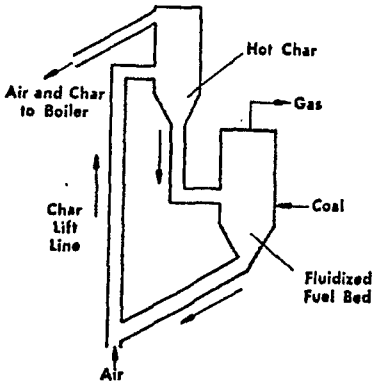
Process 33
IFE TWO-STAGE



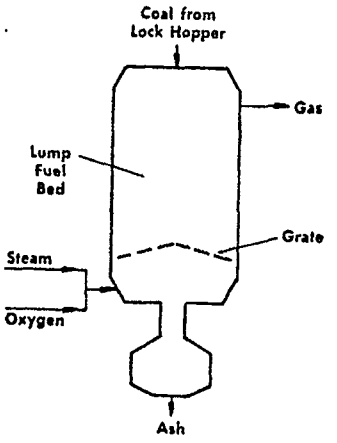
Process 34
BAMAG-WINKLER ATMOSPHERIC



Process 35
RUHRGAS VORTEX



Process 36
LR PROCESS



Process 37
LURGI DRY-ASH

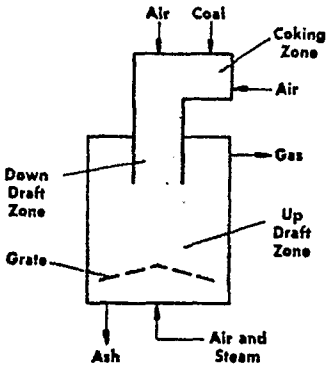
TABLE 3-1. SUMMARY OF AVAILABLE DATA ON COMMERCIAL AND PILOT-SCALE GASIFICATION PROCESSES (Continued)

Process No.	III. Commercial Fuel Gas Processes Using Air and Coal	Contact Method	Pressure	Process Characteristics	Reactor Description	Reactor Diagram	Plant Description	Flow Diagram	Specific Performance	Material Balance	Heat Balance	Fuel Analysis	Gas Analysis	Reagent Cost
31	Power-Gas Mechanical	Fx	A	S	S	S	S	S	S	S	S	I	S	S
32	Wellman-Galusha	Fx	A	S	S	S	S	S	S	S	S	S	S	S
33	IFE Two-stage	Fx	A	S	S	S	S	S	N	N	N	N	N	N
34	Bamag-Winkler Atmospheric	Fl	A	S	S	S	N	N	S	S	S	S	S	S
35	Ruhrgas Vortex	En	A	S	S	S	S	S	S	S	S	S	S	N
36	LR Process	En	A	S	S	S	S	N	N	N	N	N	S	N
37	Lurgi Dry-ash	Fx	E	S	S	S	N	N	S	N	N	S	S	N

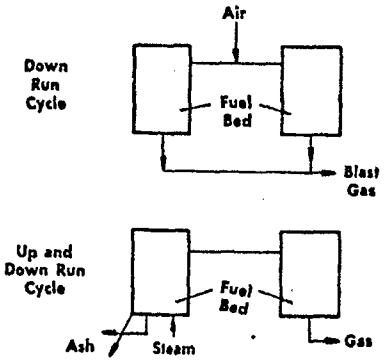
Fx = Fixed Bed
Fl = Fluidized Bed
En = Entrained

A = Atmospheric
E = Elevated

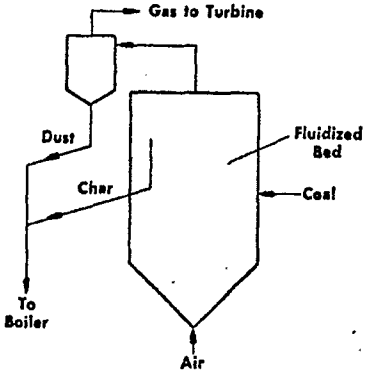
S = Data Satisfactory
I = Data Incomplete
N = No Data



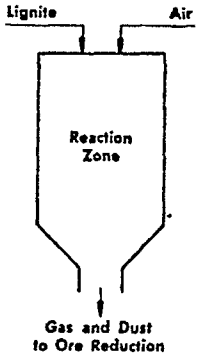
Process 38
BCR-KAISER



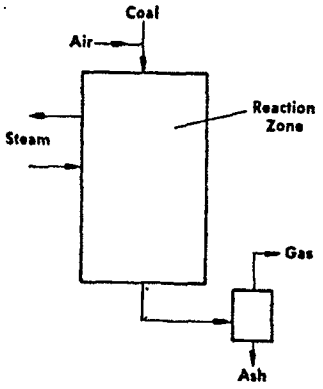
Process 39
BASF-FLESCH DEMAG



Process 40
CEGB MARCHWOOD



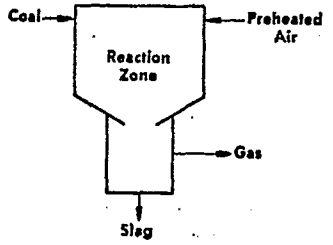
Process 41
GREAT NORTHERN RAILWAY



Process 42
PANINDCO

No Data Available

Process 43
B & W CYCLONE



Process 44
FRS CYCLONE

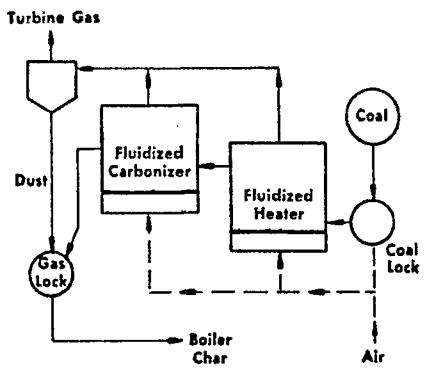
TABLE 3-1. SUMMARY OF AVAILABLE DATA ON COMMERCIAL AND PILOT-SCALE GASIFICATION PROCESSES (Concluded)

Process No.	IV. Pilot-scale Fuel Gas Processes Using Air and Coal	Contact Method	Pressure	Process Characteristics	Reactor Description	Reactor Diagram	Plant Description	Flow Diagram	Specific Performance	Material Balance	Heat Balance	Fuel Analysis	Gas Analysis	Reagent Cost
38	BCR-Kaiser	Fx	A	S	S	S	N	N						
39	BASF-Flesch-Demag	FxFl	A	S	S	S	N	N	N	S	S	I	S	S
40	CEGB Marchwood	Fl	E	S	S	S	S	S						
41	Great Northern Railway	En	A	S	S	S	S	N						
42	Panindco	En	A	S	S	S	S	S						
43	B & W Cyclone	En	N	N	N	N	N	N						
44	FRS Cyclone	En	A	S	S	I	N	N						

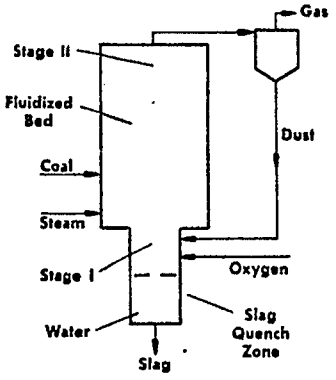
Fx = Fixed Bed
Fl = Fluidized Bed
En = Entrained

A = Atmospheric
E = Elevated

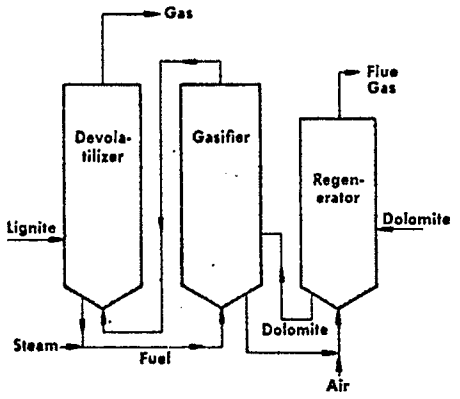
S = Data Satisfactory
I = Data Incomplete
N = No Data



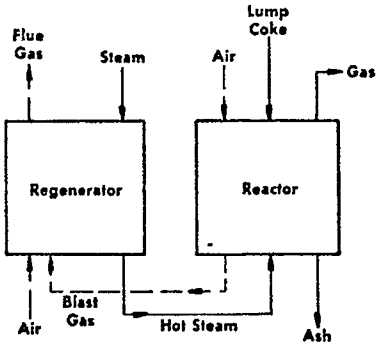
Process 45
BECHTEL CARBONIZER



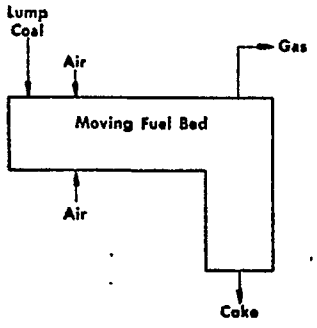
Process 46
TWO-STAGE FLUIDIZED SUPER-PRESSURE



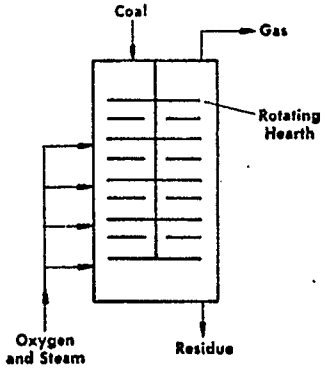
Process 47
CO_2 ACCEPTOR



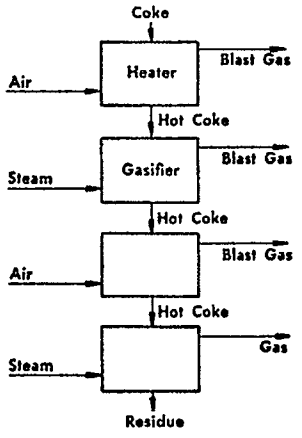
Process 48
STOOKEY



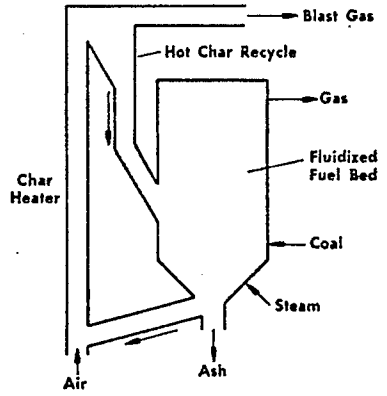
Process 49
CHEM-COKE



Process 50
NICHOLS-HERRESHOFF FURNACE



Process 51
CAMERON AND JONES



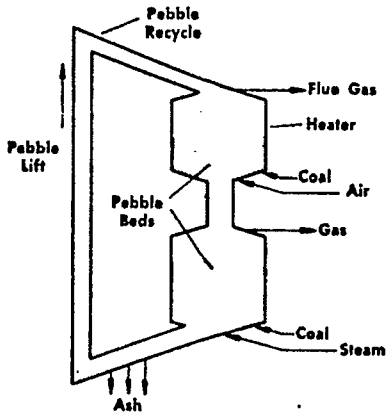
Process 52
STANDARD OIL FLUIDIZED-BED

TABLE 3-2. PROPOSED CONCEPTUAL PROCESSES

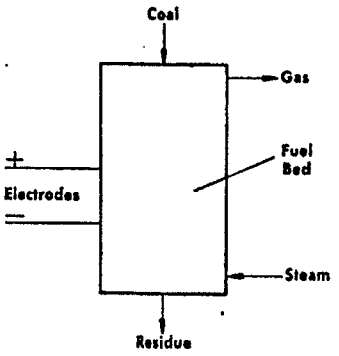
Process No.		Coal Size	Pressure	Source of Data
	I. Fuel Gas Using Air			
45	Bechtel Carbonizer	I	E	U
46	Two-stage Fluidized Super-pressure	I	SP	U
	II. Synthesis Gas Using Air			
47	CO_2 Acceptor	C	E	U
48	Stookey	C	A	U
49	Chemcoke	C	A	U
50	Nichols-Herreshoff	C	A	U
51	Cameron and Jones	C	A	U
52	Standard Oil Fluidized-bed	I	A	P

LEGEND

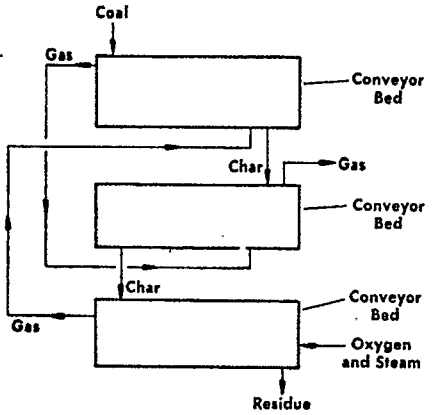
Coal Size	Pressure	Publication
C = Coarse or Briquet	A = Atmospheric	U = Unpublished
I = Intermediate	E = Elevated	P = Published
P = Pulverized	SP = Above 1000 psi	
	NA = Not Available	



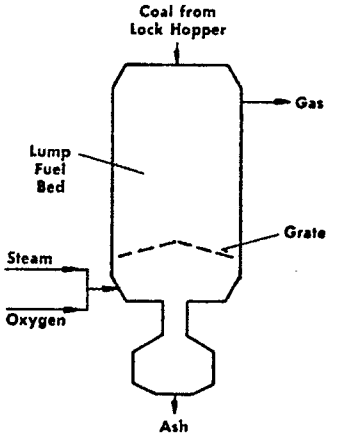
Process 53
MAYLAND PEBBLE-BED



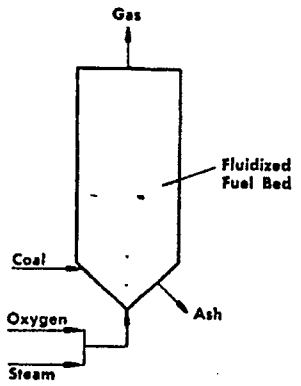
Process 54
JENSEN ELECTRIC



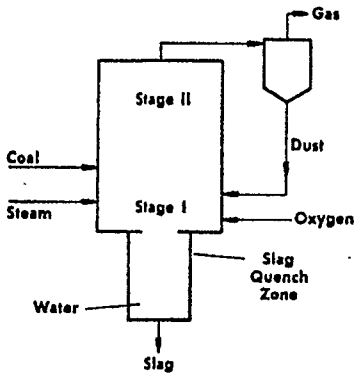
Process 55
MULTI-STAGE CONVEYOR



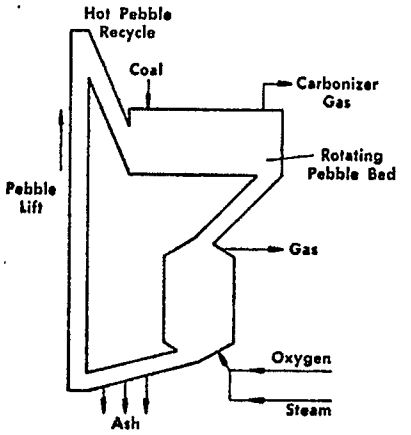
Process 56
FIXED-BED SUPER-PRESSURE



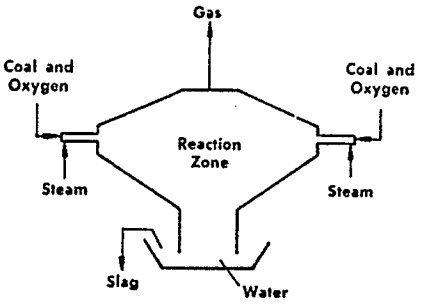
Process 57
FLUIDIZED-BED SUPER-PRESSURE



Process 58
TWO-STAGE SUPER-PRESSURE ENTRAINED



Process 59
MAYLAND PEBBLE-BED



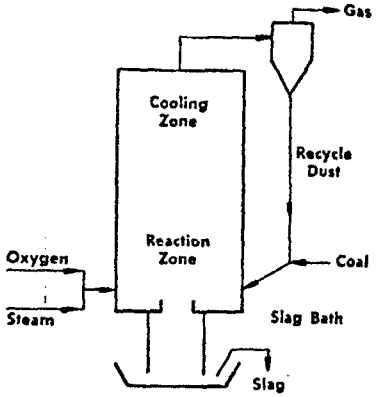
Process 60
KOPPERS-TOTZEK PRESSURIZED

TABLE 3-2. PROPOSED CONCEPTUAL PROCESSES (Continued)

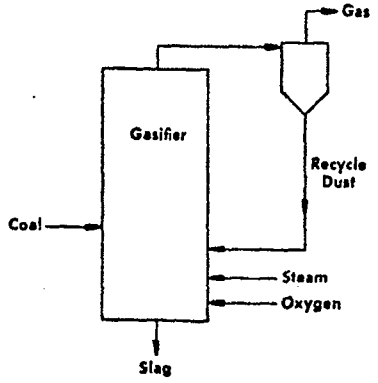
Process No.	II. Synthesis Gas Using Air (Continued)	Coal Size	Pressure	Source of Data
53	Mayland Pebble-bed	P	NA	P
54	Jensen Electric	C	A	P
	III. Synthesis Gas Using Oxygen			
55	Multi-stage Conveyor	C	E	U
56	Fixed-bed Super-pressure	C	SP	U
57	Fluidized-bed Super-pressure	I	SP	U
58	Two-stage Super-pressure Entrained	I or P	SP	U
59	Mayland Pebble-bed	P	NA	P
60	Koppers-Totzek Pressurized	P	E	U

LEGEND

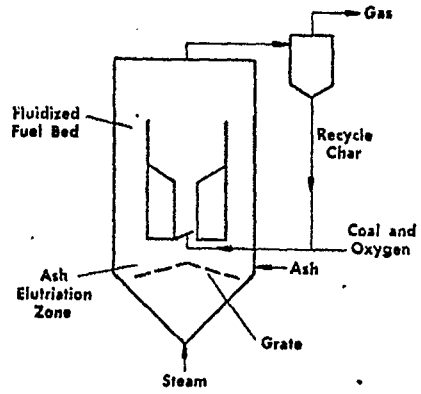
Coal Size	Pressure	Publication
C = Coarse or Briquet	A = Atmospheric	U = Unpublished
I = Intermediate	E = Elevated	P = Published
P = Pulverized	SP = Above 1000 psi	
	NA = Not Available	



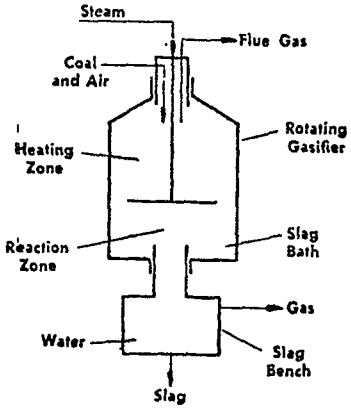
Process 61
RUMMEL SINGLE-SHAFT PRESSURIZED



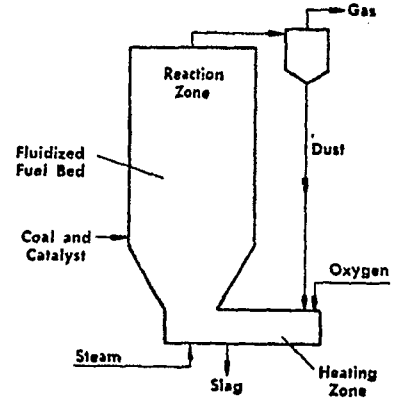
Process 62
RUMMEL MODIFIED SINGLE-SHAFT PRESSURIZED



Process 63
GAS COUNCIL FLUIDIZED-BED



Process 64
MACCORMAC-RUMMEL DOUBLE-SHAFT



Process 65
CATALYTIC STEAM METHANATION

TABLE 3-2. PROPOSED CONCEPTUAL PROCESSES (Concluded)

Process No.	III. Synthesis Gas Using Oxygen (Continued)	Coal Size	Pressure	Source of Data
61	Rummel Single-shaft Pressurized	P	E	U
62	Rummel Modified Single-shaft Pressurized	P	E	U
63	Gas Council Fluidized-bed	I	E	U
64	Maccormac-Rummel Double-shaft	P	A	U
65	Catalytic Steam Methanation	P	I	U

LEGEND

Coal Size	Pressure	Publication
C = Coarse or Briquet	A = Atmospheric	U = Unpublished
I = Intermediate	E = Elevated	P = Published
P = Pulverized	SP = Above 1000 psi	
	NA = Not Available	