What is Vision 21?

Vision 21 is a government/industry cost-shared partnership to develop the design basis for *integrated* energy plants that will, early in the 21st century, result in the deployment of *ultra-clean* plants that can produce *affordable* electricity, transportation fuels, and other high-value products from feedstocks that include coal, gas, biomass, and "opportunity fuels."

CURRENT US ENERGY USE AND COAL USE FOR THE FUTURE

by

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US Energy Sources (2005)

Total: 2.5x10exp(17) BTU/yr

Renewables: 6.3x10exp(15) BTU/yr = 2.4% of total

Hydroelectric: 2.7x10exp(15) BTU/yr

Biomass: 2.97x10exp(15) BTU/yr including wood, waste and alcohols

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I. Introduction
II. Fossil-Fuel Resources
III. Resources for Nuclear Fission, Breeder, and Fusion Reactors
IV. Renewable Resources
V. Recent Estimates of Fossil-Fuel Reserves and Resources Likely to Become Usable over the Near Term
VI. The Kyoto Protocol
VII. Policy Considerations

GLOSSARY

Fossil fuels Coals, petroleums, natural gases, oils from shales and tar sands, methane hydrates, and any other supplies from which hydrocarbons for energy applications may be extracted.

Fuels for nuclear breeder reactors These include U-238 and Th-232, which may be converted to fissile isotopes (e.g., U-233, U-235, Pu-239, and Pu-241) as the result of neutron capture.

Fuels for (nuclear) fission reactors The naturally occurring fissile isotope U-235, as well as Pu-239 and Pu-241 produced by neutron capture in U-238 and U-233 from Th-232.

Fuels for (nuclear) fusion reactors Deuterium-2 (which occurs in water as HDO or D_2O) and Li-6, which constitutes about 7.4% of naturally occurring lithium.

Nonrenewable resources (nonrenewables) Resources located on the planet with estimable times for exhaustion at allowable costs and use rates.

Renewable resources (renewables) Usually defined as extraterrestrial energy supplies such as solar resources, but some authors include energy supplies of such types and magnitudes that they will be available for the estimated duration of human habitation on the planet.

Reserves Energy supplies which are immediately usable at or very close to current prices.

Resources The totality of energy supplies of specified types that include reserves and may become usable in time at competitive prices with improved technologies.

AN ASSESSMENT of energy reserves and resources is properly made in the context of needs for an acceptable standard of living for all humans. This approach may be quantified by beginning with a discussion of current energy use in a developed country such as the United States, noting ascertainable benefits from high energy-use levels, estimating the possible impacts of a vigorously pursued,

Encyclopedia of Physical Science and Technology, Third Edition, Volume 5

TABLE I Worldwide Energy Resources without Consideration of Utilization Efficiencies or Technical Readiness[a]

"Nonrenewable" energy sources	Energy (EJ) (1 EJ = 10^{18} J = 10^{25} erg)	Years of availability at 2×10^3 EJ/yr
Fusion energy from D in 1.5×10^{18} m^3 of water	1×10^{13}	5×10^9
Uranium in the earth's crust used in breeder reactors	6×10^{12}	3×10^9
Uranium in the earth's crust used in fission reactors	4×10^{10}	2×10^7
Fusion of lithium contained in seawater	3×10^9	1.5×10^6
Uranium in seawater used in breeder reactors	4×10^8	2×10^5
Uranium in seawater used in fission reactors	4×10^6	2×10^3
Worldwide fossil-fuel resources (shale oils, coals, oils from tar sands, petroleum, natural gas, natural gas liquids)	$>2 \times 10^6$	$>1 \times 10^3$
U.S. conventional Oil resources	$\sim 1 \times 10^5$	$\sim 5 \times 10$
Fusion of lithium in terrestrial Li_2O deposits	8×10^4	4×10
Hydrothermal energy stored to a depth of 10 km worldwide	4×10^4	2×10
U.S. uranium used in water-moderated fission reactors	2×10^4	1×10
Hydrothermal energy stored to a depth of 3 km worldwide	8×10^3	4

"Renewable" energy sources	Power (EJ/yr)	Multiple of need at 2×10^3 EJ/yr
Solar energy at the "outer boundary" of the atmosphere[b]	5×10^6	2.5×10^3
Worldwide wind energy	2×10^6	1×10^3
Ocean thermal energy conversion (OTEC)[c]	3.78×10^5	190
Geothermal energy (outward flow of heat from the earth's core)	8×10^2	4×10^{-1}
Tidal energy	1×10^2	5×10^{-2}
Hydroelectric energy worldwide	9×10^1	4.5×10^{-2}
Commercial, worldwide energy use in 1995	4×10^2	—
Stabilized annual worldwide energy demand as of 2050 with conservation for 10×10^9 people and allowance of energy use to establish an acceptable standard of living for all[d]	2×10^3	—

[a] See the text for sources of these values.

[b] This is the total solar input which may be recovered in part as biomass, wind energy, OTEC, direct water photolysis, photovoltaic energy, etc.

[c] A 1964 assessment is 2×10^3 EJ for the Gulf Stream alone. If 0.1% of the solar input power is used for tropical waters with accessible temperature differences >22°C (area ≈ 60×10^6 km^2), the continuous power production is 12×10^6 GW_e year = 378×10^3 EJ/year.

[d] This long-range, steady-state value refers to 10×10^9 people (now expected by the year 2050) with each person using 60% of the U.S. *per capita* consumption of 1998, i.e. each person enjoying the average 1998 U.S. standard of living if conservation efforts lead to a 40% energy-use reduction over the long term.

Session Explores New Sources of Oil and Gas*

Heavy oils and natural gas hydrates, which exist in vast reserves, could potentially become a significant source of energy, but these resources are much more difficult and expensive to produce than conventional sources of oil and natural gas. At a March Meeting session on the future of fossil fuels and a related press conference, speakers provided assessments of these potential alternative sources of oil and natural gas.

Natural gas consumption has been rising rapidly, and is expected to increase 70% by 2025, said Timothy Collett of USGS. The United States currently consumes about 25 trillion cubic feet of natural gas per year. *

An alternative could be found in gas hydrates, reported Collett. Hydrates are ice-like solids, in which water molecules trap the methane molecules in a cage-like structure. Hydrates look a lot like ordinary ice, but they burn when lit with a match.

Like conventional natural gas, most gas hydrates are methane-based, and thus produce relatively clean burning fuel. Burning methane adds less carbon dioxide to the atmosphere than burning coal or oil.

1983, can be found on the sea floor near the coasts and underneath the arctic tundra. Earth contains vastly more natural gas in hydrates than in conventional natural gas, said Collett in a press conference at the March Meeting. "Hydrates are a very large, known source of natural gas," he said. There has been increasing international interest in recovering and using these resources, he said.

Several missions have recently explored some of these deposits and estimated how much natural gas hydrate they contain. Estimates range from 100,000 to 300,000,000 trillion cubic feet of natural gas hydrates on Earth, compared with 13,000 trillion cubic feet of conventional natural gas. The US has about 320,000 trillion cubic feet of gas hydrates, but only 1200 trillion cubic feet of conventional natural gas reserves.

More research is underway to assess more accurately how much hydrate natural gas exists and how much of it might be recoverable, Collett said.

Recovering the gas is challenging, but possible.

Years of known US gas-hydrate supplies at current use rates = 320,000 trillion cubic feet/25 trillion cubic feet = 12,800 years

Years of conventional US gas reserves at current use rates = 1200 trillion cubic feet/25 trillion cubic feet = 48 years

END 1999 ESTIMATES OF RECOVERABLE COAL RESERVES (Wikipedia 2007)

Country	Bituminous (including anthracite)	Sub-bituminous	Lignite	TOTAL
United States of America	115891	101021	33082	249994
Russian Federation	49088	97472	10450	157010
People's Republic of China	62200	33700	18600	114500
India	82396		2000	84396
Australia	42550	1840	37700	82090
Germany	23000		43000	66000
South Africa	49520			49520
Ukraine	16274	15946	1933	34153
Kazakhstan	31000		3000	34000
Poland	20300		1860	22160
Serbia, Montenegro	64	1460	14732	16256
Brazil		11929		11929
[illegible]	[illegible]	[illegible]		[illegible]

COAL GASIFICATION:

DIRECT APPLICATIONS AND SYNTHESES OF CHEMICALS AND FUELS[†]

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2006 WORLDWIDE COAL USE: 5.3 billion mt with 75% used for 40% of worldwide electricity generation

China, India and adjacent countries used 1.7 billion mt with projected growth by 2025 to 2.7 billion mt.

Worldwide coal use has recently been growing at about 25% in 3 years.

Best efficiency for electricity generation has averaged about 35% but should reach about 45% with higher T, p.

World coal reserves at current use rates will last about 300 years (British Petroleum estimate).

Coke from low-ash, low-sulfur bituminous coal (formed at 800 to 1000 degrees C) is the fuel of choice in smelting iron ore in blast furnaces; by-products include coal tar, ammonia, light oils, "coal gas."

Coal Gasification with Steam and Oxygen is used to produce Syngas (hydrogen + carbon monoxide +…) which is comparable to NG

Coal Liquefaction is accomplished via the Fischer-Tropsch Synthesis (used first in Germany and then worldwide promoted by Sasol (South Africa). The process involves coal gasification to make $CO + H_2$; on passage over a suitable catalyst, light HCs are formed.

These light HCs, in turn, produce gasoline or diesel fuel or methanol in the presence of suitably selected catalysts; methanol may be converted to gasoline by using, for example, the Mobil M-gas process.

Other processes for making liquid fuels are the Bergius Process (developed in Germany during the nineteen twenties) and the Gulf Oil Solvent Refined Processes SRCI and SRC II (developed during the 1960s and 1970s). In both of these processes, coal is gasified to light hydrocarbons. In the Bergius process, liquid fuels are then made by further reaction with hydrogen; in the Gulf oil processes, liquid fuels are made by direct conversion of light hydrocarbons to fuels.

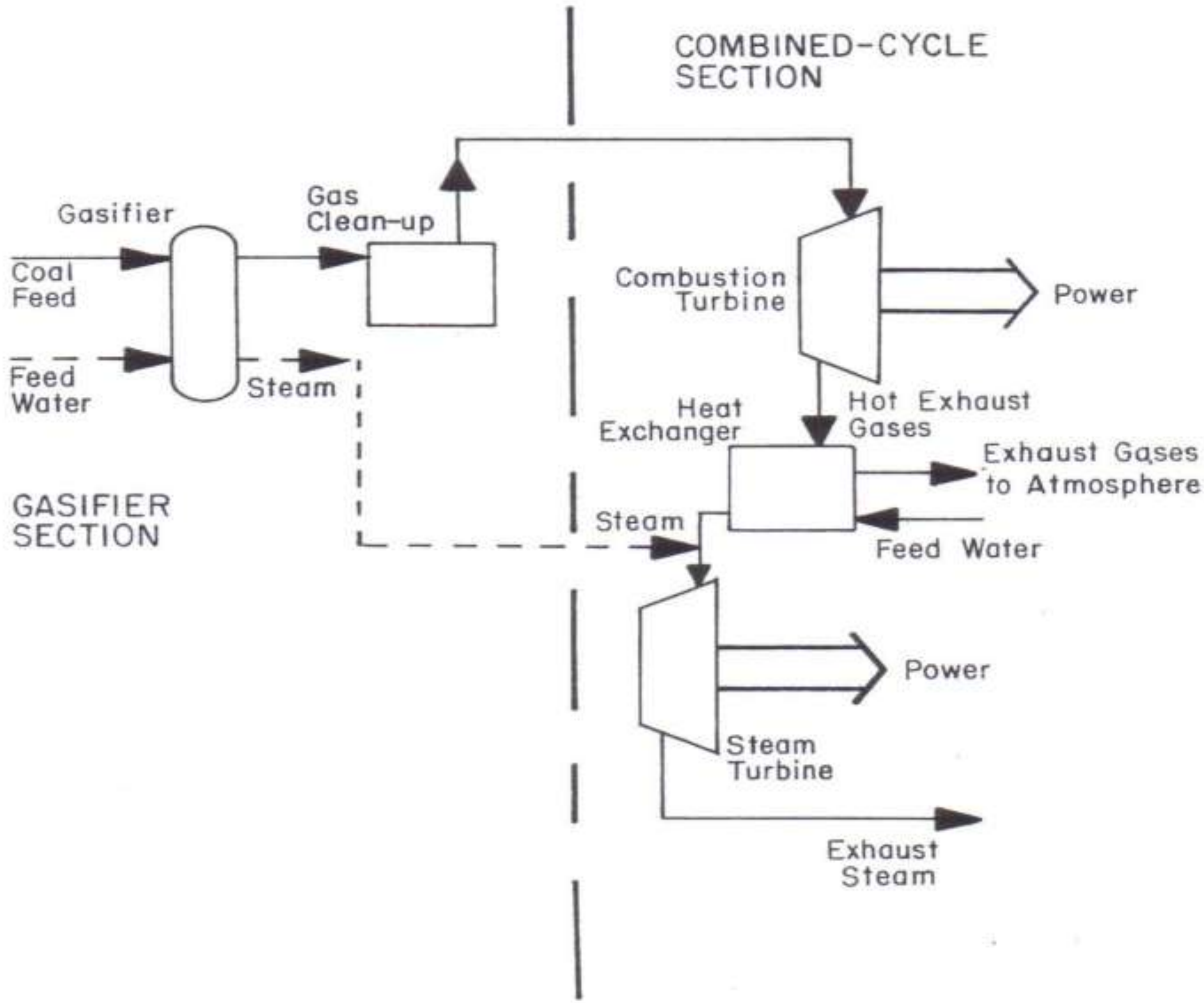


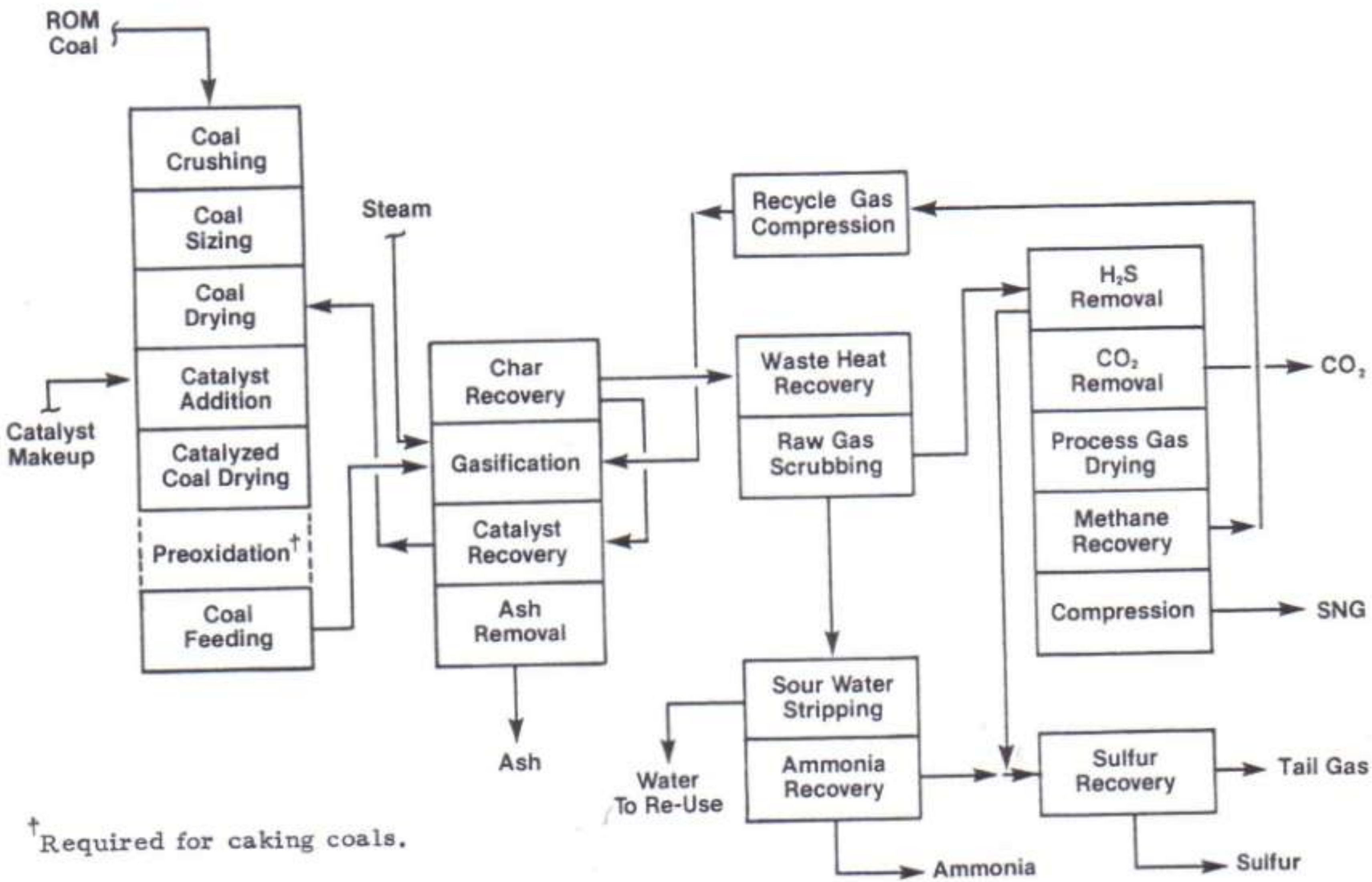
Fig. 3.1-1. Schematic drawing showing a generic IGCC system.

Table 3.1-1. Status of selected coal-gasification technologies.

Manufacturer	Operating Plants
Texaco	Cool Water: 2 × 1000 TPD; 117 MW_e; Ube: 4 × 500 TPD; Tennessee Eastman: 2 × 900 TPD; Ruhrchemie: 1 × 600 TPD
Shell	250 TPD pilot plant in TX
Dow	160 MW_e IGCC at Plaquemine, LA; 1 × 2,500 TPD gasifiers
BGC/Lurgi	600 TPD at Westfield, Scotland
Allis-Chalmers	600 TPD at Wood River
KRW	35 TPD at Waltz Mills; 500 TPD in China (1989 start-up)
IGT	40 TPD at Chicago; 200 TPD proposed for France

Table 3.1-2. Future goals for 500-600 MW_e IGCC plants; reproduced from Ref. 3. Comparisons refer to conventional coal-fired plants as baseline.

About 10% higher efficiency, i.e., heat rates of 9000-9100 Btu/kWh, corresponding to 37.5-37.9% efficiency.
Lower pollutant emissions, 33% less water consumption, reduced waste-water treatment and formation of non-hazardous, useful by-products.
A 15% reduction in levelized electricity costs.
More rapid and cheaper construction of smaller modular units.



†Required for caking coals.

Fig. 4.1-2. Coal-to-SNG in the Exxon gasification process.

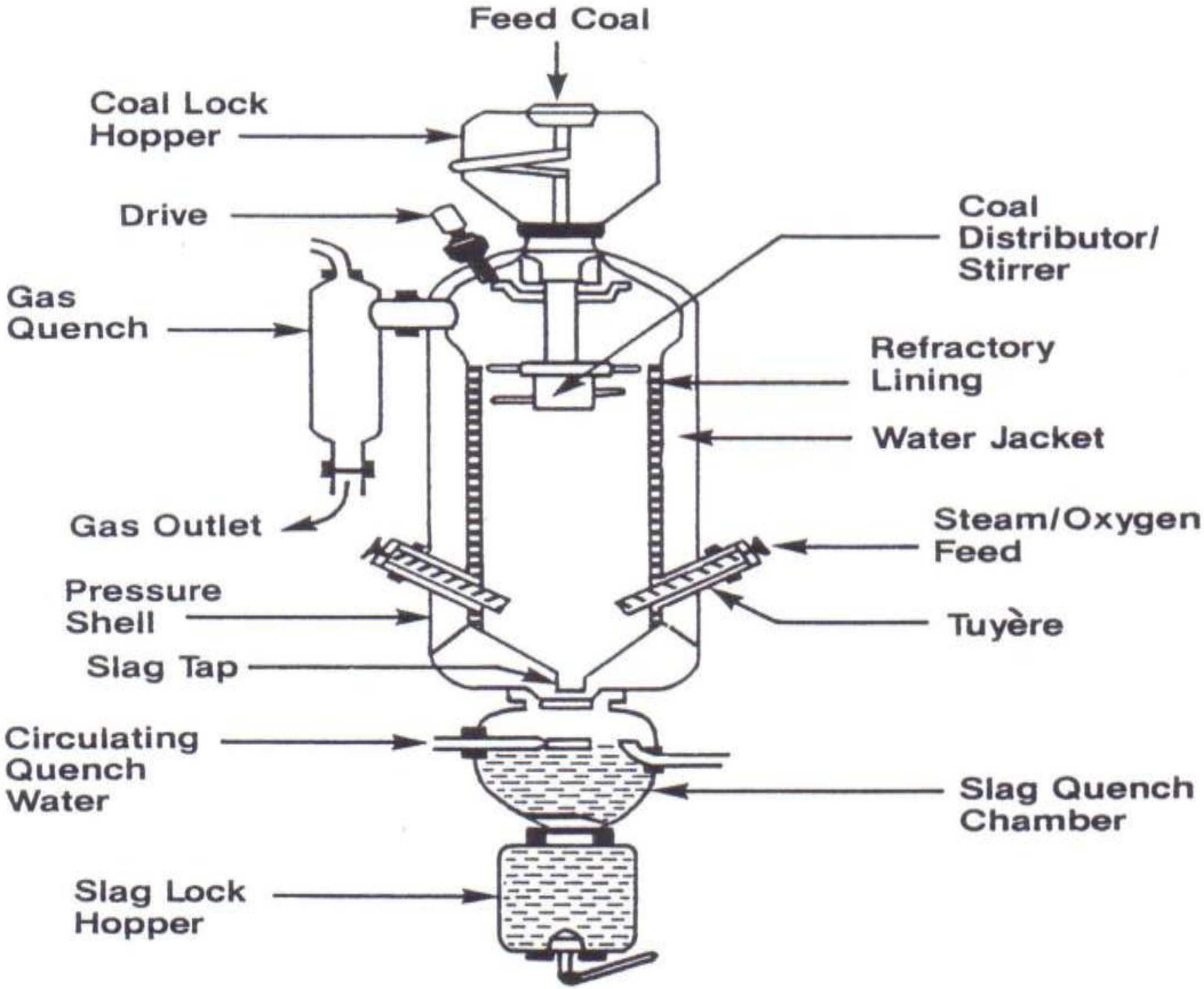


Fig. 4.2-1. The BGC/Lurgi slagging gasifier.

Peak Oil Debunked: 43. **COAL LIQUEFACTION**
At 20754000 btus/short ton, the U.S. has 5.2 x 10^18 btus of recoverable **coal** reserves. The thermal efficiency of **coal liquefaction** is about 65%. ...
peakoildebunked.blogspot.com/2005/08/43-**coal-liquefaction**.html - 25k - Cached - Similar pages

[PDF] CLEANER **COAL** TECHNOLOGY PROGRAMME
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Significant **coal liquefaction** research and development (R&D) was started ... War, both Germany and the UK had operational **coal liquefaction** plant. By ...
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Coal Liquefaction. Work at the CAER. Ed Givens, CAER. The Advanced Concepts for Direct ... Thus, CAER indirect **coal**. **liquefaction** research has been utilized ...
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The Energy Blog: About **Coal Liquefaction**
Coal liquefaction is the conversion of **coal** into a synthetic oil in order to supplement natural sources of petroleum. It is an attractive technology because ...
thefraserdomain.typepad.com/energy/2005/07/about_**coal**_liqu.html - 132k - Cached - Similar pages

coal liquefaction
www.mrw.interscience.wiley.com/ueic/articles/a07_197/frame.html - Similar pages

Asia Times Online :: China Business News - China cools down **coal** ...
Coal liquefaction is a process that converts **coal** from a solid state into liquid ... "Although **coal liquefaction** promises to help ease China's oil shortage, ...
www.atimes.com/atimes/China_Business/HJ04Cb01.html - 47k - Cached - Similar pages

Japan To Give Asia **Coal Liquefaction** Technology
Tokyo (AFP) Jun 12, 2006 - Japan plans to provide Asian nations, particularly China, with the technology to liquefy **coal** as part of a broader effort to ...
www.terradaily.com/reports/Japan_To_Give_Asia_**Coal_Liquefaction**_Technology.html - 23k - Cached - Similar pages

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Coal liquefaction; use a solvent to effect hydrogenation. Products often solid at room temperature ... **Coal liquefaction**: technically feasible, but the ...
gcep.stanford.edu/pdfs/RxsY3908kaqwVPacX9DLcQ/malhotra_**coal**_mar05.pdf - Similar pages

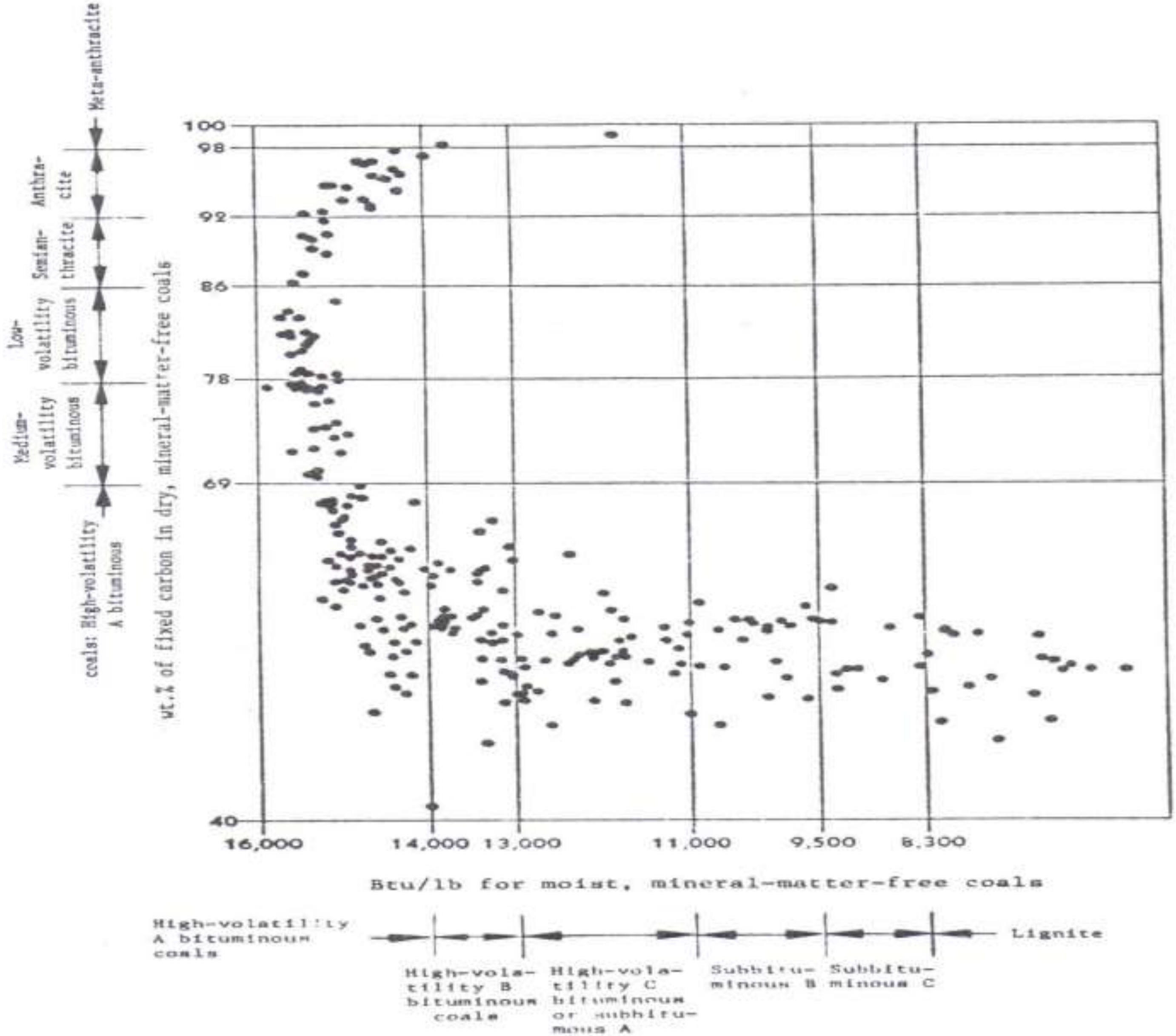
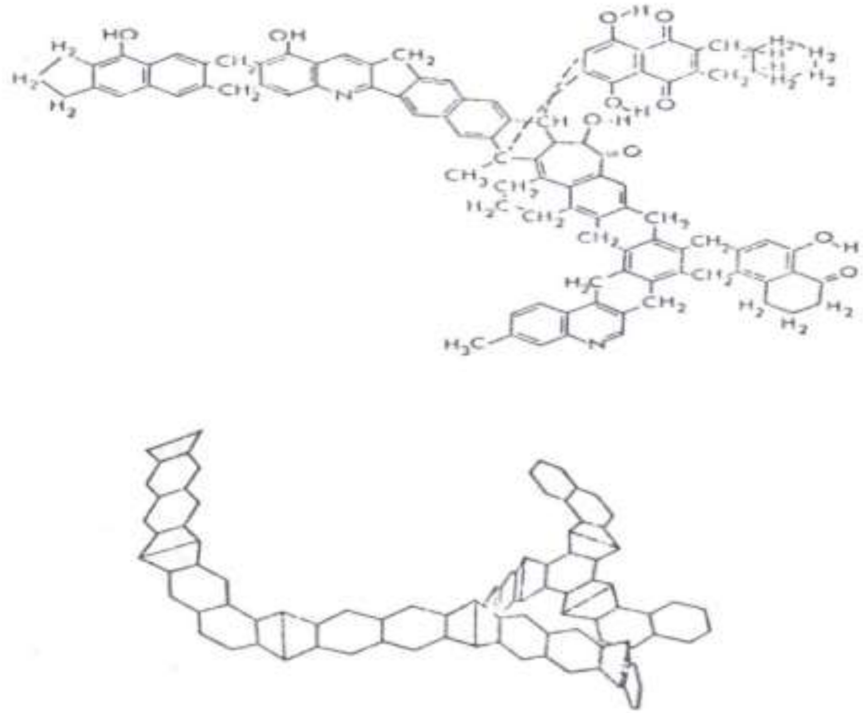


Fig. 10.1-1 Designations and ranks of U.S. coals according to a standard classification, showing energy contents per unit mass and weight percent of carbon; reprinted with permission from Ref. [1].



(a) Hypothetical coal molecule with ~82% carbon. The lower diagram, in which the shaded areas represent alicyclic structures, shows the spatial configuration of a simplified form of this molecule.

(b) Molecular structure of bituminous coal.

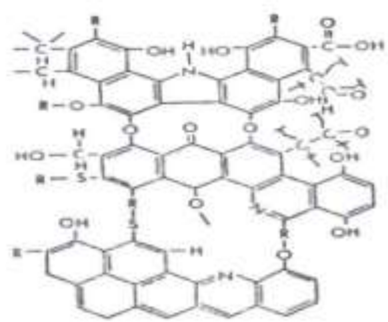


Fig. 10.1-2 Hypothetical structures of coal; reproduced from (a) P. H. Given {Ref.(93) in Ref.[3], p. 130} and (b) G. R. Hill and L. B. Lyon {Ref.(94) in Ref.[3], p. 130}.

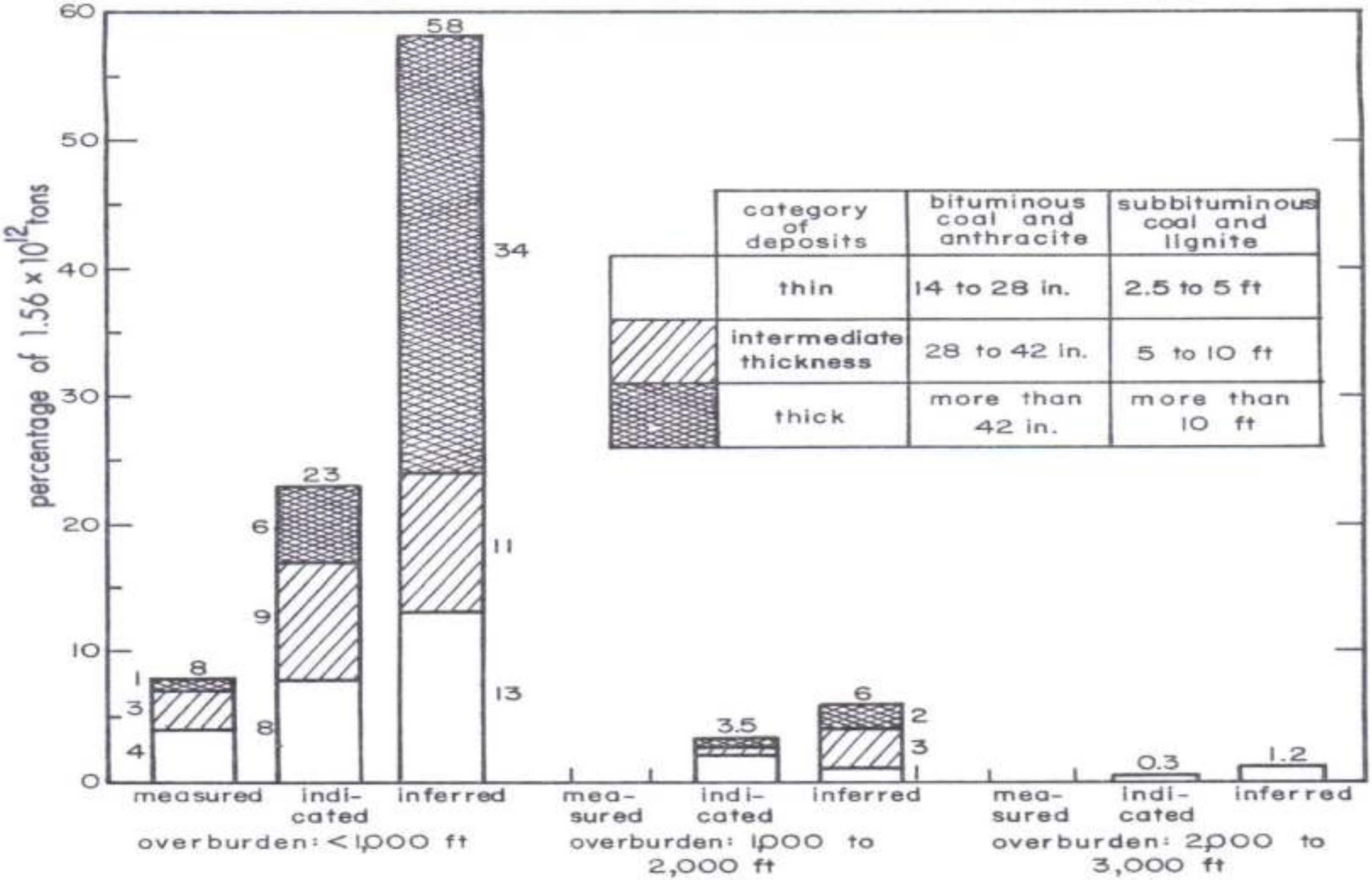


Fig. 10.2-1 Overburden for 1.56 x 10^{12} t of mapped and and explored coal resources in the U.S. The numbers adjacent to the vertical bars indicate the approximate percentages of coal contained in the specified deposit categories. The coal resources that have been either measured or indicated in shallow or moderately thick deposits with less than 1,000 ft of overburden total 3.94 x 10^{11} t. Reproduced from Ref. [3].

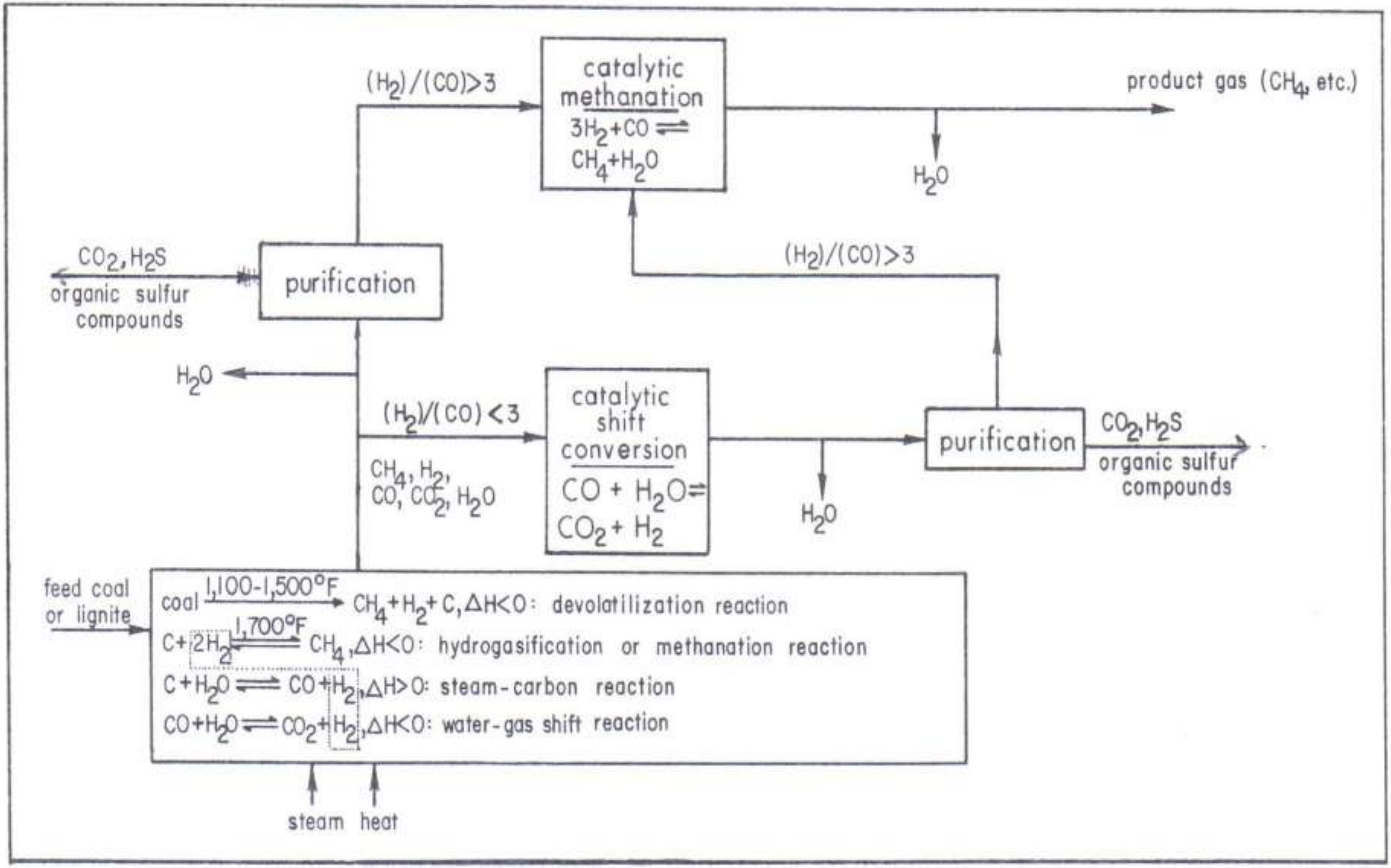


Fig. 10.3-1 General process scheme for producing methane from coal; reproduced with modifications from Ref. [1].

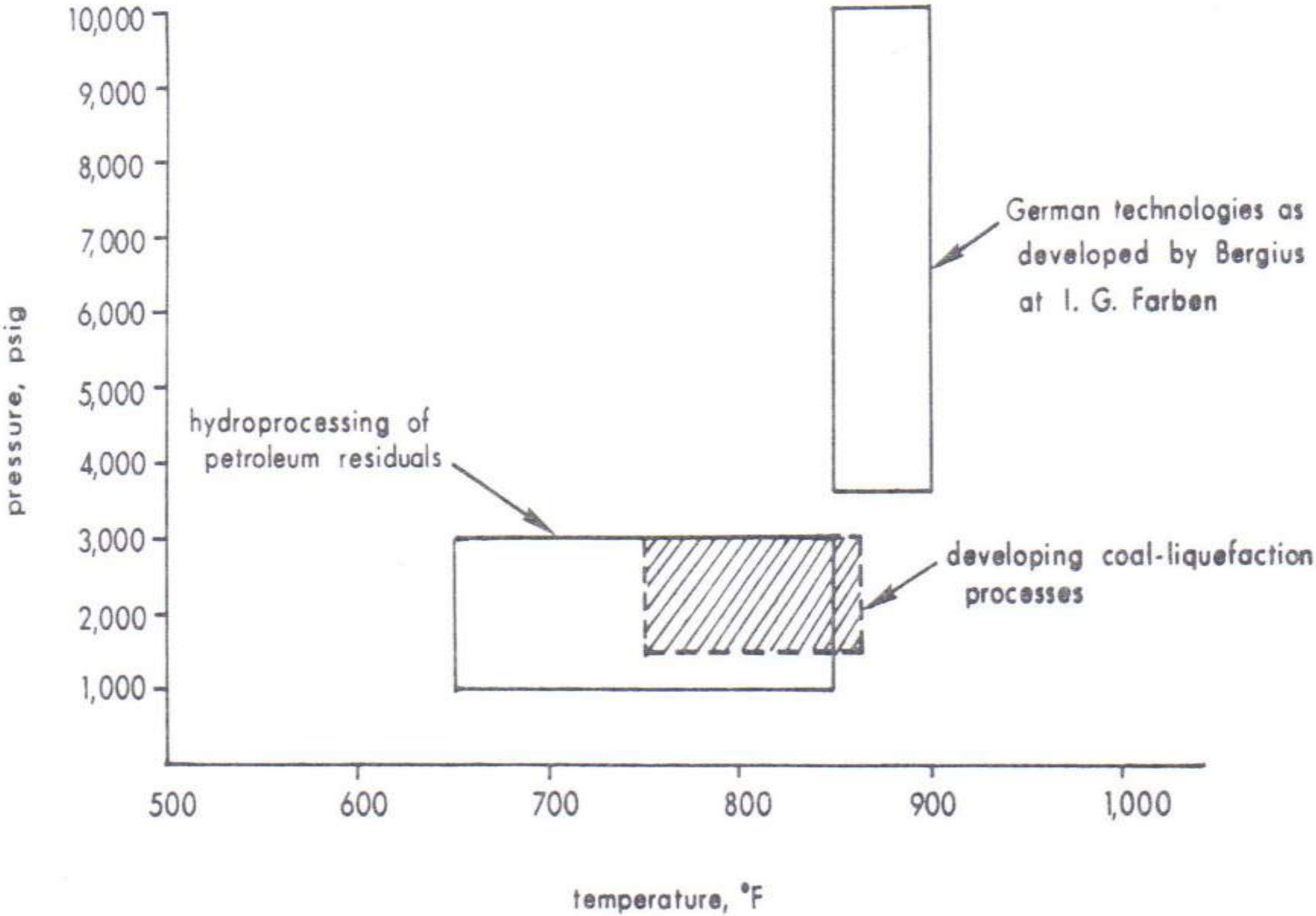

10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
pressure, psig
German technologies as developed by Bergius at I. G. Farben
hydroprocessing of petroleum residuals
developing coal-liquefaction processes
500
600
700
800
900
1,000
temperature, °F

Fig. 10.4-1 Identification of pressure and temperature regimes for early German and for developing coal-liquefaction technologies; reproduced from Ref. II.

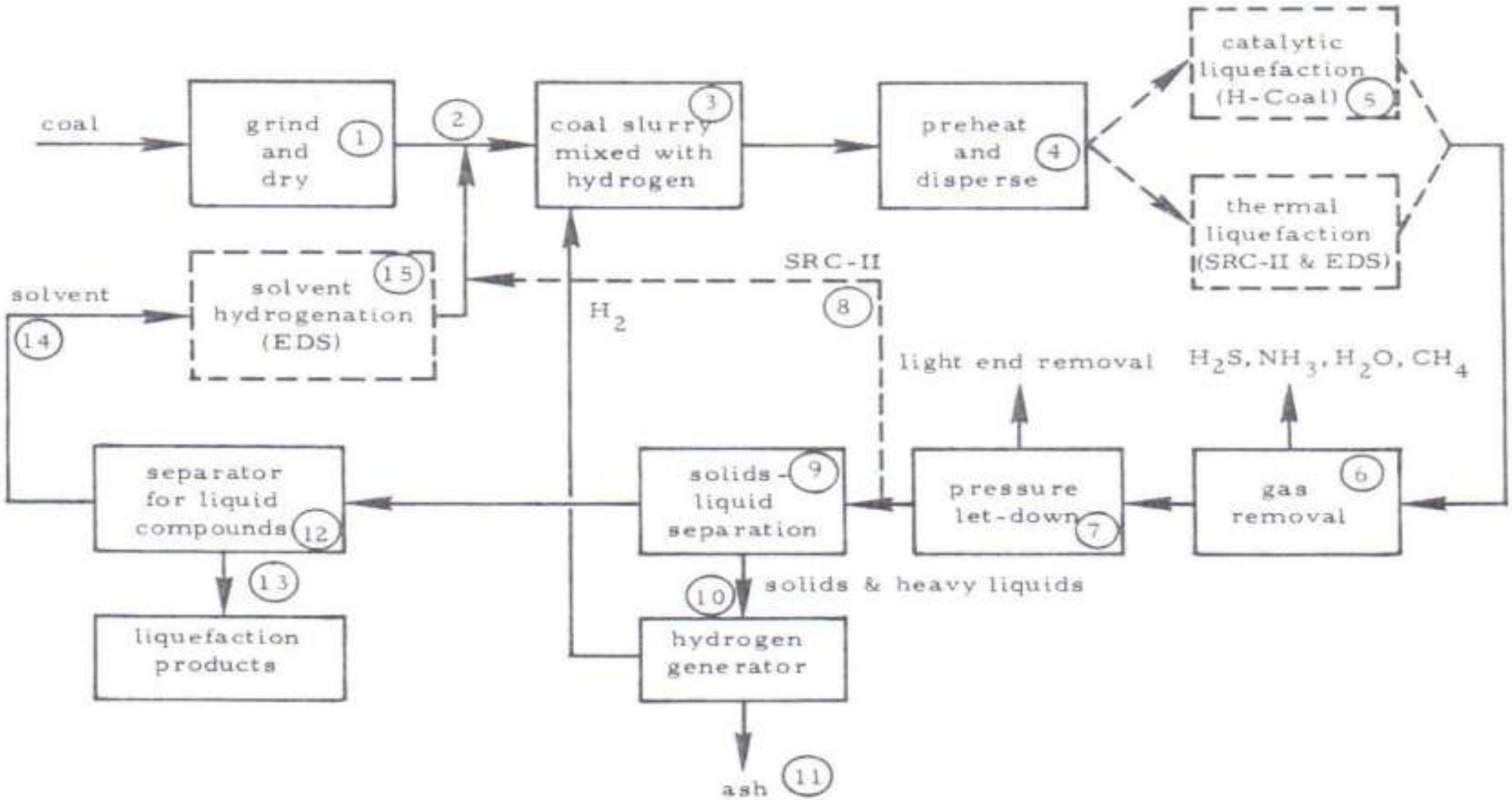


Fig. 10.4-2 Generalized flow diagram for direct coal liquefaction (after R. H. Fischer); reproduced from Ref. II.

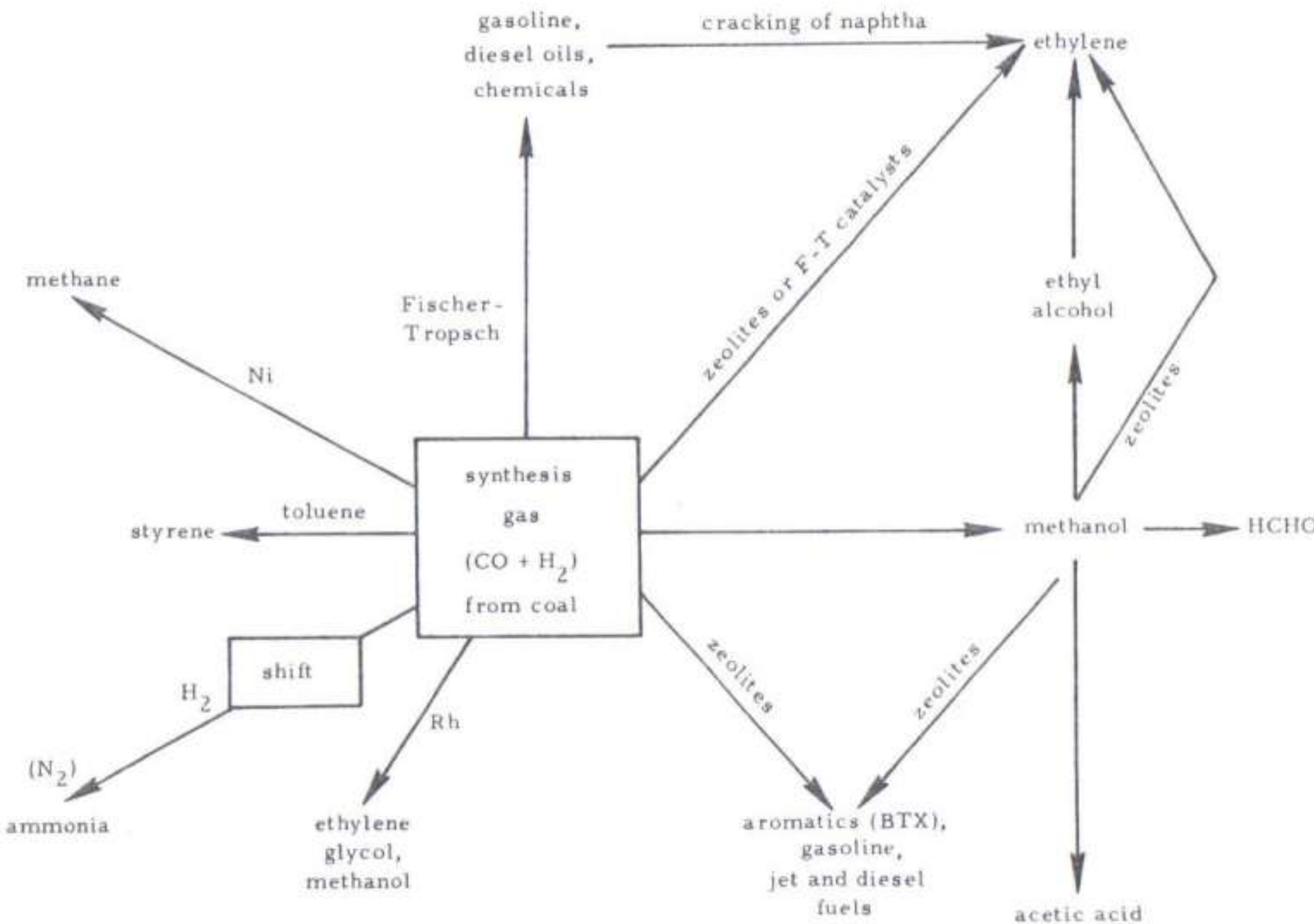


Fig. 10.4-3 Schematic overview of indirect coal-liquefaction processes processes (after I. Wender in Ref. I).

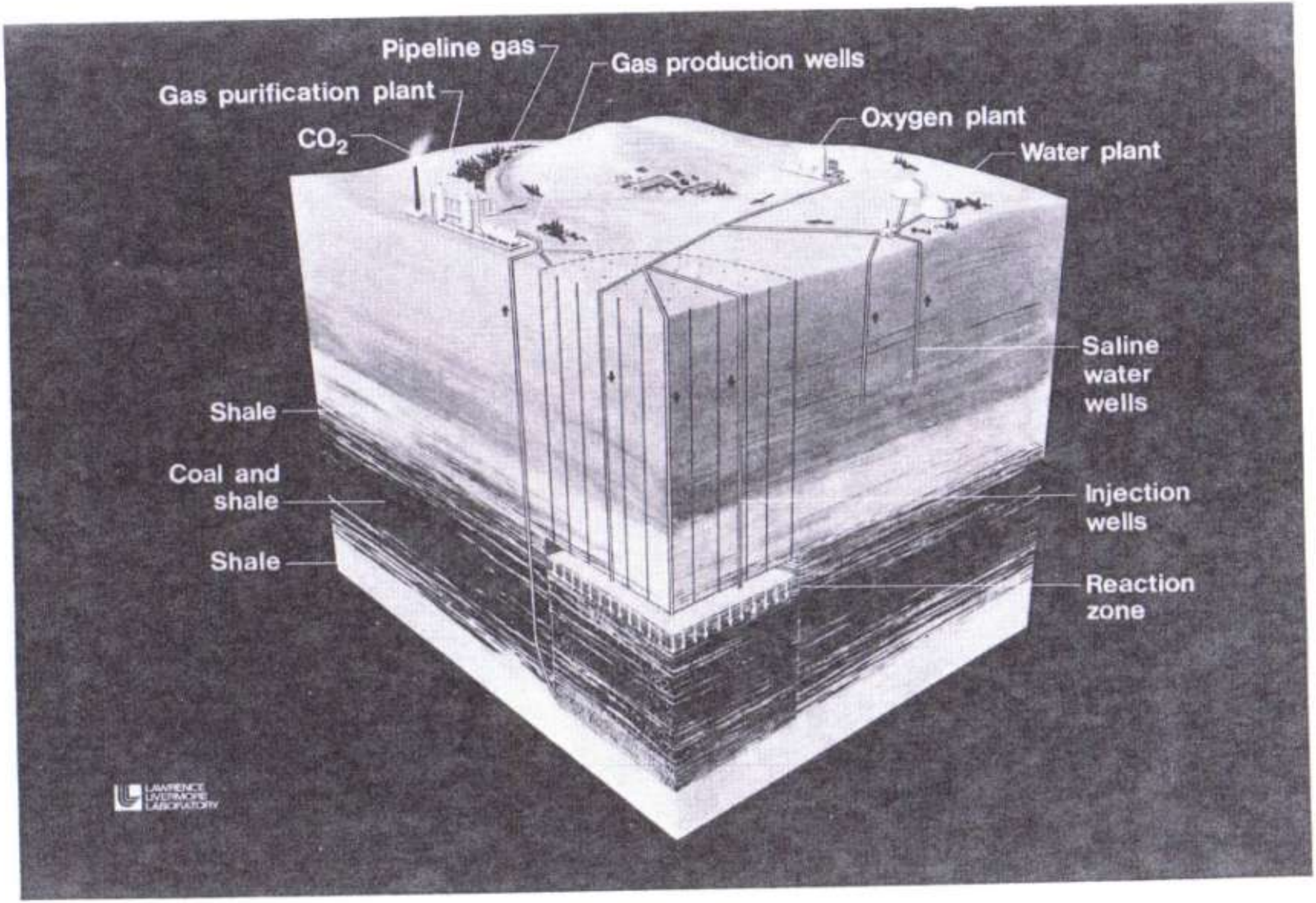


Fig. 10.5-3 Conceptual scheme proposed for in situ coal gasification; reproduced from Ref. [3]. Photograph courtesy of Lawrence Livermore Laboratory, Livermore, California.