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The Present State of the U.S. Underground Coal Gasification Program

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The Present State of the U.S. Underground Coal Gasification Program

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ABSTRACT

The Underground Coal Gasification Program in the United States is reviewed briefly from its inception to the present day. The current U.S. program, the Rocky Mountain 1 Underground Coal Gasification test, is described in some detail. A short description of planned future activities is also given.

The Present State of the U.S. Underground Coal Gasification Program*

Introduction

The underground coal gasification program in the United States began in 1946 with the experiments done by the U.S. Bureau of Mines at Gorgas, Alabama.[1,2] These tests continued intermittently until 1959.

Although the results of some of the tests looked promising, the economics of underground coal gasification did not look attractive compared to cheap and plentiful natural gas that was being distributed by pipeline all over the country during that same period. The program was abandoned and no more work was done until the high oil prices of the 1970's once again encouraged work on alternate energy sources.

The Hanna 1 experiment[3] in 1973-74 was the first experiment of this new phase and it was done by the Bureau of Mines Laboratory at Laramie, Wyoming, which later became the Laramie Energy Technology Center (LETC) when the Department of Energy (DOE) was created. This encouraging but inconclusive test was followed by the successful Hanna 2 series[4,5,6] of tests in 1975 and 1976.

At about the same time, the Lawrence Livermore National Laboratory (LLNL) was asked by the Atomic Energy Commission tobegin research in alternate energy programs and we conducted a test near Gillette, Wyoming, called Hoe Creek 1 in 1976.[7]

The Texas Utilities Corp. bought the patent rights to the Russian technology and their subsidiary, Basic Resources,[8] carried out their first test in Texas lignite in 1976, with assistance from the Russian engineers.

The results from this initial period of renewed research were encouraging enough so that an energetic, although always modestly funded, program of laboratory, modeling and field work was carried out over the next ten years.

Some new participants joined the program. The Texas A&M University, with a combination of state and private funding, developed an independent program in a lignite seam.[9] The Atlantic Richfield Corp. (ARCO) carried out a very successful test in the 30-meter thick Wyodack coal seam at their Rocky Hills[10] site near Hoe Creek, Wyoming. Gulf Oil Co., operating under contract to the DOE did two experiments in a steeply dipping coal seam near Rawlins, Wyoming.[11,12] The Morgantown Energy Technology Center (METC) carried out a gasification test in a

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270-meter deep swelling bituminous coal seam near Pricetown,[13] West Virginia. Tables 1 and 2 list the names and pertinent facts concerning the tests done to date.

Not all of the tests were equally successful, but all of them produced very important information that has been extremely helpful in providing the degree of understanding of the process that we have today. Continuity of experience is very important. The value of the work done at Gorgas was, to a large extent, lost because the group had been disbanded and there was no easy way to establish continuity with the new group of experimenters.

The tests at Hanna were extremely important in demonstrating that high quality gas and good coal recovery can be achieved repeatedly if the site is chosen carefully enough. The moderately thick, low permeability, dry coal with a strong, dry overburden is just about ideal for UCG. However, even at this site, the presence of a major fault crossing the gasifier, as in the Hanna 4 experiment,[14] showed the importance of careful site characterization.

The Hoe Creek experiments were designed to test various linking methods and, as such, were very successful. They also clearly showed the effect on the gas composition of the wet overburden. Two of the most important things shown by these tests were the clear demonstration of the importance of the position of the injection point[15] and the first demonstration of full steam/oxygen[16] gasification.

The Rawlins tests gave the clearest indication yet that UCG may very well be economically competitive at the present time, given the right resource in the right market area. The process of steeply dipping bed gasification applied to a thick, dry shrinking coal seam like the one at Rawlins, Wyoming, may not be foolproof but it comes very close to it. Because of the natural gravity feed of the dried coal rubble, made as the hot gases travel up dip to the production well, the coal is gasified in an ever renewing bed just above the injection point. The burns tend to be wider than for horizontal beds and pyrolysis gases are mainly produced above the fire zone and escape with less cracking. The economic outlook for steeply dipping bed gasification looks very favorable, even at today's oil price.

The tests at Centralia, Washington,[17,18] showed for the first time that the CRIP process does work as predicted and does provide an additional means of controlling the gas quality. These tests were also a good demonstration of gasification in a high wall geometry, (economic stripping ratio reached), which may be a very economical way of extending the useful life of open pit mines. Certainly one of the most important contributions made by these tests was the opportunity to observe the actual results of the gasification by excavating the cavities. All who witnessed even part of that excavation gained some new understanding of what the underground process is like.

TABLE 1. Summary of U.S. DOE-sponsored UCG field tests (forward gasification phase)

Test	Year	Duration (days)	Coal gasified (tons)	Gas Quality (Btu/scf)	Gas Quality (kCal/m^3)	Cold Gas* thermal efficiency %
Laramie Energy Technology Center -- Hanna, Wyoming Site						
I	1973-1974	168	2720	126	1121	77
II-1A	1975	37	962	137	1219	85
II-1B	1975	38	780	143	1273	86
II-II	1976	26	2201	168	1495	92
II-III	1976	39	3414	132	1175	77
III	1977	38	2663	138	1228	77
IV-A(a)	1978	7	294	109	970	78
IV-A(b)	1978	48	3184	102	908	73
IV-B(a)	1979	7	468	149	1326	95
IV-B(b)	1979	16	663	122	1086	83
Lawrence Livermore National Laboratory -- Hoe Creek, Wyoming Site						
I	1976	11	123	101	899	82
II(air)	1977	13	286	108	961	80
II(O_2)	1977	2	47	263	2341	88
II(air)	1977	43	1155	104	926	74
III(air)	1979	7	256	113	1006	81
III(O_2)	1979	47	3251	212	1887	73
Centralia, Washington Site						
LBK(O_2)	1981-82	20	140	262-284	2332-2528	80
(air)				140	1246	
CRIP(O_2)	1983	28	2000	248	2207	74
Morgantown Energy Technology Center -- Pricetown, West Virginia Site						
I	1979	17	234	149	1326	97
Gulf Research and Development Co. -- Rawlins, Wyoming Site						
I(air)	1979	30	1207	151	1344	91
I(O_2)	1979	5	125	250	2225	74
II(O_2)	1981	66	8550	330	2937	88

*Ratio of heating value of gas to heating value of the coal used in deriving the gas.

TABLE 2. Privately sponsored UCG field tests in USA

Test	Year	Duration (days)	Coal gasified (tons)	Gas quality (Btu/scf)	(kCal/M^3)	Cold gas thermal efficiency (%)
<u>Basic Resources, Inc.</u>						
Fairfield, TX	1976	26	—	126	1121	—
Tennessee Colony, TX:						
Air injection	1978-79	197	4000-5000	81	721	—
Oxygen injection		10	212	230	2047	—
<u>ARCO Coal Co., Reno Junction, WY</u>						
Rocky Hill I (air)	1978	60	3600	200	1780	94
<u>Texas A&M University (with Industrial Consortium)</u>						
College Station, TX	1977	1	2	35-114	311-1015	—
Bastrop County, TX	1979	2	—	85	757	—
Bastrop County, TX	1980	—	—	35-150	311-1335	

The Present Program

Government-sponsored research in underground coal gasification is done under the auspices of the Office of Fossil Energy of the Department of Energy (DOE). This office is headed by Assistant Secretary, Fossil Energy, J. Allen Wampler, and Principal Deputy Assistant Secretary, Donald L. Bauer. The Deputy Assistant Secretary for Oil, Gas, Shale and Special Technologies, Marvin Singer, is in charge of two offices, one of which, the Office of Oil, Gas, and Shale Technology whose Director is Douglas Uthus, controls the underground coal gasification program through Program Manager, Edward L. Burwell.

These offices, located at DOE Headquarters in Germantown, Maryland, determine overall program planning, policy and budgetary matters. Program implementation, planning and budgeting, setting technical objectives and technology transfer are done at the Morgantown Energy Technology Center (METC) the Director is A. Pitrolo. The work is done under the direction of H. Guthrie, Director of Extraction Projects with UCG Program Manager, J. Martin. METC also administers several small research contracts with universities and private industry. METC is a DOE owned and operated laboratory at Morgantown, West Virginia. Table 3 shows this organization in more detail.

At the present time, other than by direct contract to industry, the DOE research program is implemented mainly through two special agencies, The Western Research Institute (WRI) and Lawrence Livermore National Laboratory.

The Western Research Institute is owned and operated by the University of Wyoming and is staffed predominantly by personnel from the old Laramie Energy Technology Center which has been deactivated. Funds for this laboratory come from private sources and from government contracts and grants during the transition period from federal to private status. WRI does energy-related research and development on a contract basis for private industry and for various government agencies. Their major thrust areas at present are in oil shale, tar sands, coal and environmental work. They have had major responsibility for the environmental monitoring and water clean-up programs at the old gasification sites in Wyoming as well as the new site characterization work. WRI was responsible for the post burn excavation work at the Centralia Partial Seam CRIP Test site. The Institute is headed by Director W. Barnes with J. Covell, Manager of Coal Technology and B. Racenski, Manager of the Environmental Office.

The Lawrence Livermore National Laboratory (LLNL) is operated for the DOE by the University of California and, although it is mainly a nuclear weapons design laboratory, it does have a number of energy-related programs including underground coal gasification. All LLNL programs are either DOE sponsored or approved by DOE in the case of work for others contracts.

TABLE 3

UNDERGROUND COAL GASIFICATION ORGANIZATION

J. WAMPLER, ASSISTANT SECRETARY FOR FOSSIL ENERGY

D. BAUER, PRINCIPLE DEPUTY ASSISTANT SECRETARY FOR FOSSIL ENERGY

M. SINGER, DEPUTY ASSISTANT SECRETARY (ACTING) FOR OIL, GAS, SHALE AND SPECIAL TECHNOLOGIES

D. UTHUS, DIRECTOR, OFFICE OF OIL, GAS, AND SHALE TECHNOLOGY

E. BURWELL, UCR/UCG PROGRAM MANAGER

POLICY
PLANNING
STRATEGIC OBJECTIVES

A. PITROLO, DIRECTOR, METC
T. BECHTEL, ASSOCIATE DIRECTOR, OFFICE OF TECHNICAL MANAGEMENT

P. WIEBER, DEPUTY ASSOCIATE DIRECTOR OFFICE OF TECHNICAL MANAGEMENT

H. GUTHRIE, DIRECTOR, EXTRACTION PROJECTS MANAGEMENT DIVISION

T. BARTKE, DIRECTOR, METC/LPO

J. MARTIN, UCG PROGRAM MANAGER METC/LPO

IMPLEMENTATION
PLANNING/BUDGET
TECHNICAL OBJECTIVES AND TECHNOLOGY TRANSFER

The largest UCG project currently active in the United States is a 10 million dollar joint industry-government project called the Rocky Mountain 1 test.[19] This test, financed 60% by a consortium of private industry and 40% by the DOE, is being managed by the Sponsors Management Committee headed by the Gas Research Institute (GRI). Besides GRI, the other consortium members are American Oil Company (AMOCO), Rocky Mountain Energy Corp. (RME) and the Electric Power Research Institute (EPRI). The Stearns Roger Division of United Engineers & Constructors is the prime contractor and they have hired Energy International Inc. (EI) as their operational consultant and Resource Enterprise as their drilling consultant.

The DOE provides some direct funds and some indirect funds by assigning LLNL and WRI to support certain aspects of the test with moneys budgeted to them. WRI has had primary responsibility for site characterization and environmental support as well as some operational support during the test. LLNL is responsible for supplying and operating the gas analysis and data acquisition systems and for general design and operational support. We are also supplying a large amount of equipment left over from previous tests and loaning some LLNL-owned equipment.

This test, which is to be carried out at the Hanna, Wyoming, test site owned by the Rocky Mountain Energy Corporation, is designed to answer many of the unresolved technical and economic questions left from previous U.S. testing.

The primary objectives of the program are to:

1. Identify and measure the necessary data for the economic evaluation of appropriate commercial UCG options.

2. Identify and measure the data necessary to develop plans to actively control any possible environmental impacts.

3. Identify and quantify the factors which control resource recovery.

4. Identify and measure the data necessary to design a prototype surface processing facility.

The test design, which is illustrated in Figure 1, consists of two gasification modules to be operated simultaneously side-by-side for a period of up to 100 days. The two modules differ in design in that one is a larger copy of the Centralia CRIP test design and the other, the ELW, extended linked vertical well system, is a modification of the linked vertical well design but with vertical injection wells and production through the directionally drilled link. The modules will be separated far enough so that the burn cavities will not join together and information can be gathered as to the maximum cavity widths that can be achieved for acceptable gas composition. Present plans are to operate

The Rocky Mountain 1 test

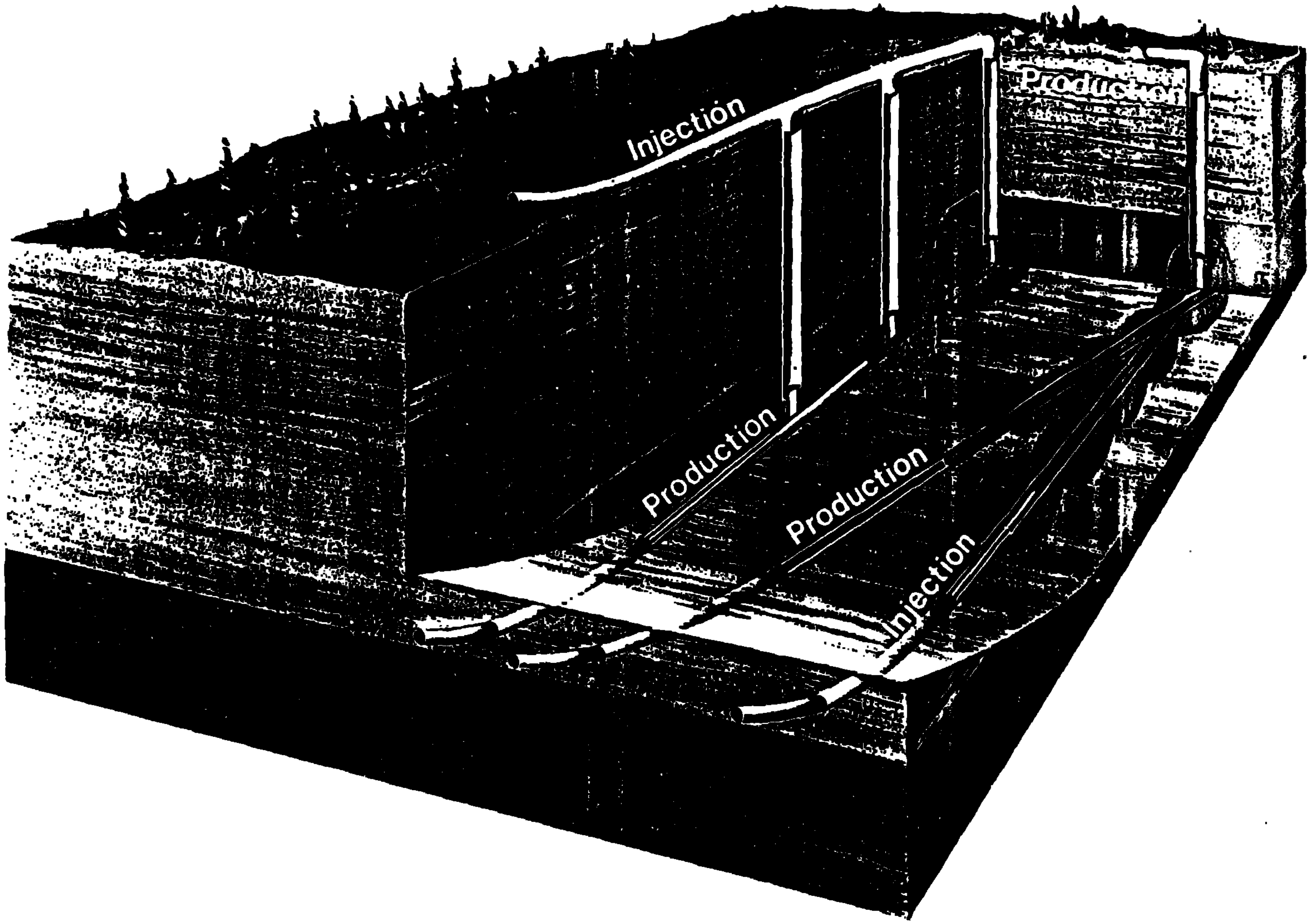

Figure 1. Artist's conception of the Rocky Mountain 1 test. The CRIP module is on the right and the ELW module on the left of the picture.

both modules so that the injection points are not moved until the cavities have grown so large that the gas quality is seriously affected. The modules are long enough so that at least three cavities can be formed in each module. This will be the first time in the DOE program where multiple cavities have been made in continuous sequence.

The Controlled Retracting Injection Point, or CRIP,[20] process was developed in response to data from the Hoe Creek tests which indicated that the gas quality was much improved by injecting at the bottom of the coal seam rather than at the top, in a seam with high heat loss due to water influx. The injection is done through a metal pipe or liner placed in the directionally drilled link well. This not only insures that the injection point remains at the bottom but provides a means of moving the injection point when the cavity has reached maximum size by burning off a section of the liner and starting a new cavity.

Another goal of the CRIP process development was to provide a means of gasifying very thick coal seams where the survival of vertical injection wells through periods of massive roof collapse is very doubtful. Although the thickness of the Hanna seam is only 10 meters and vertical injection wells have survived in other tests at this site, the tests, where failure of the injection well occurred, did produce somewhat lower quality gas. Also, this area of the Hanna test site is wetter than the original site and thus we feel that this test will still provide us with a good opportunity to compare horizontal, bottom seam injection with vertical injection. It will also allow us to check out the mechanical design of a movable ignitor and pipe cutter system over a long period of operation and to assess the difficulty of inserting long injection liners in directionally drilled holes.

The use of the horizontal production well for the CRIP module is a carryover from the Centralia test where the increase in pyrolysis gas along the long open hole did make a significant improvement in total gas quality. The use here in this test will allow us to determine the effect on the overall economics of the additional drilling cost compared to the surface pipeline cost.

The ELW module also uses a horizontal production well to increase production of pyrolysis gases but the main reason for using the link well for production is to avoid the safety problems associated with using vertical wells for both production and oxygen injection. It is planned to link the first injection well to the drilled channel by mechanical means if possible, otherwise reverse combustion will be used. Subsequent injection wells will be linked by reverse combustion as they are needed.

The directional drilling requirements imposed for this test were considerably more stringent than those for our previous tests. The large size (9-7/8") hole required for the production well casing, the desire to use measure-while-drilling (MWD) directional control, and the concern for possible problems in inserting the CRIP injection liner, all pointed to a need for a large, powerful drill rig. The relatively shallow depth of the coal seam (115 m) meant that for the usual type of directional drilling, at about 5 degrees per 30 meter radius, a slant angle rig would be required. Cost estimates for this, including the extra pipe length required, were very high so the decision was made to contract for a medium radius (20 deg/30m) capability at a lower cost although at a somewhat higher risk with such a new technology. With the shorter radius hole, a vertical entry is possible which simplifies rig selection as well as shortening the major pipe runs.

All three directional holes will be cased from the surface to the bottom of the coal seam. The two production wells will be left as open holes in the coal and the CRIP injection well will have a stainless steel liner inserted through the open hole in the coal. The CRIP module production well is designed to cross over on top of the injection well so that linking to it will occur early in the first burn. A vertical production well is provided for temporary use during the initial linking step. It will be linked to the injection well either by direct intersection or by reverse combustion, if necessary. We plan to use a silane-methane ignitor system similar to that used for the Centralia test for igniting both modules. LLNL is providing this system. Figure 2 shows the proposed drilling plan for the CRIP injection well.

The proposed average and maximum flow rates are shown in Table 4 for both modules. We expect to operate at the average levels most of the time to give as steady an output as the underground conditions will permit. A program for testing the effect of varying the injection flow rates, the steam-oxygen ratios and the system pressures has been worked out and will be implemented in the field as circumstances allow.

Site characterization work has been completed by WRI at the Hanna, Wyoming site. Approximately 30 holes were drilled, some core holes for lithologic information, some for permanent water monitoring wells for environmental permit information and some for detailed hydrological data. The site chosen is about 450 meters east of the sites of the previous tests done at Hanna. There is one major fault in the northeast corner of the area with a 10 meter vertical offset. The coal is approximately 15 meters deep and 10 meters thick. The seam dips 7 degrees to the north east and since the experiment axis runs west to east, the apparent dip along the drilled channel is only 2 degrees. The coal seam is quite uniform in thickness and there appear to be no major faults in the test zone.

The hydrological test program was quite extensive using both slug injection tests and single and multiple well draw-down tests. The average permeability in the coal seam is 132 md, which is about 10 times higher than at the other Hanna sites, 5 times higher than that at the Centralia Partial Seam CRIP test site and about half of that at the Hoe Creek site. Figure 3 shows the permeabilities in milli darcy around the various test holes at the site. The process wells are also shown for orientation.

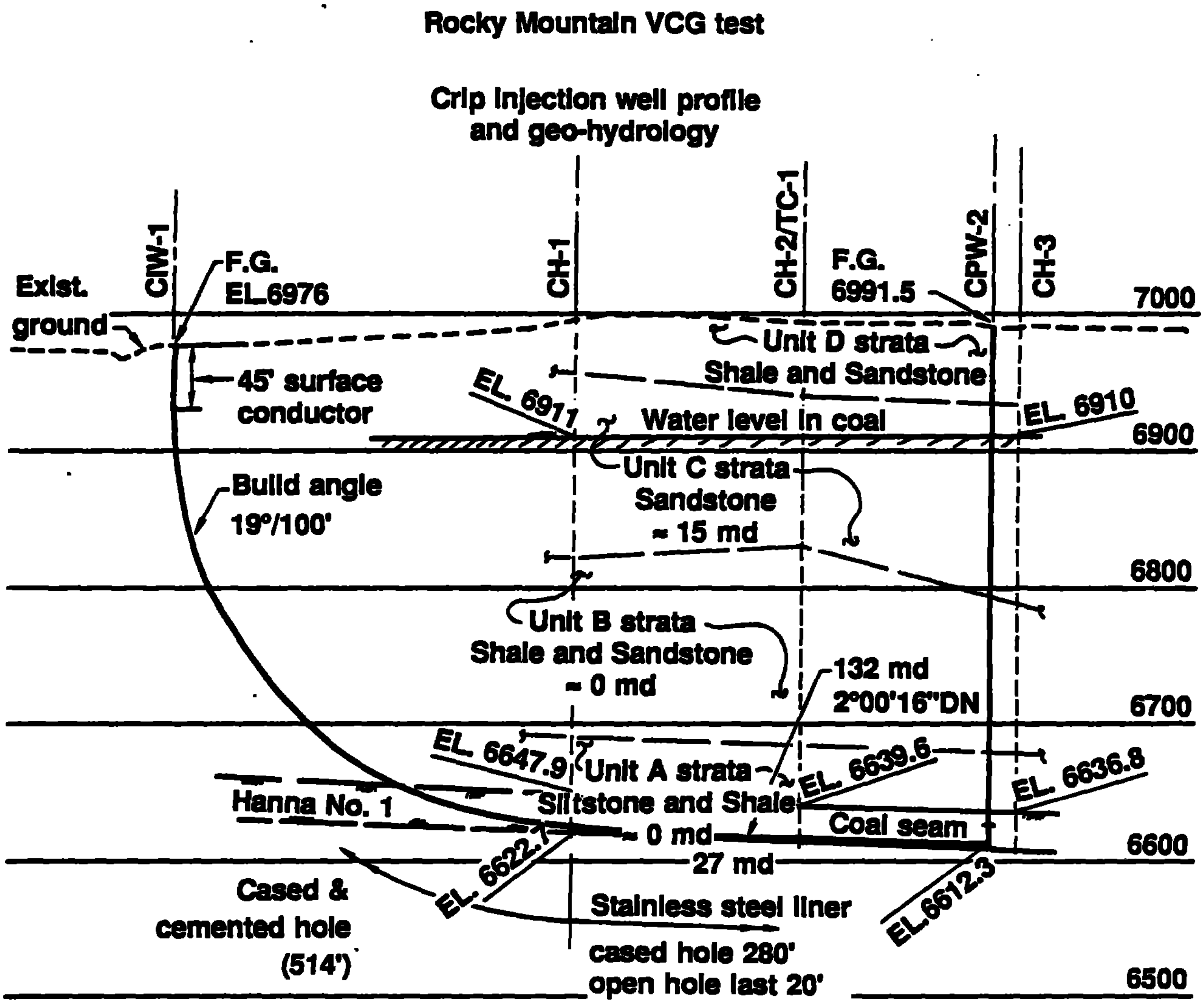

Figure 2. Rocky Mountain 1 CRIP module injection well drilling plan. Average permeabilities in md are shown for the various geologic units.

TABLE 4

PROCESS FLOW ASSUMPTIONS

PROCESS PARAMETER	VALUE		BASIS
Steam/oxygen Ratio	1.0 - 3.0		1.0 - minimum dilution of O_2 for safety 3.0 - maximum estimated for effects
Oxygen Flow Rate (Per well)			Estimated minimum rate to sustain gas quality
	Min* 300 SCFM Nom. 750 SCFM	509 m^3/hr 1274 m^3/hr	Optimum oxygen flux rates in air observed in Hanna plus 250 SCFM
Note: Maximum and nominal flow rates may not be possible at minimum pressure due to pressure drop limitations	Max 1200 SCFM	2039 m^3/hr	
Oxygen Flow Rate (Total both modules)	Min. 600 SCFM Nom. 1500 SCFM Max. 2000 SCFM	1019 m^3/hr 2548 m^3/hr 3398 m^3/hr	Maximum O_2 will not be required simultaneously in each module
Oxygen Pressure (Injection Casing shoe or end of liner)	Min. 24 PSIG Nom. 72 PSIG Max. 96 PSIG 180 PSIG	165 kPa 496 kPa 661 kPa 1240 kPa	20% Hydrostatic 75% Hydrostatic 80% Hydrostatic 150% Hydrostatic (not normal operating mode)
Injection Steam Flow Rate (Per well)	855 Lb/hr 2853 Lb/hr 5706 Lb/hr (300/1000/2000 SCFM)	388 kg/hr 1294 kg/m 2588 kg/m (509/1699/3398 m^3/hr)	Minimum ST/O_2 ratio Most likely steady state ratio Most likely ratio at max O_2 flow
Injection Steam flow rate (Total both modules)	1712 Lb/hr 5706 Lb/hr 8558 Lb/hr (600/2000/3000 SCFM)	776 kg/hr 2588 kg/hr 3882 kg/hr (1019/3398/5097 m^3/m)	Maximum ST/O_2 ratio will not be required at high O_2 flows

Table 4 (Contd.)

PROCESS PARAMETER	VALUE			BASIS
Steam Pressure	Min.	24 PSIG	165 kPa	20% hydrostatic
(Injection Casing Shoe	Nom.	72 PSIG	496 kPa	75% hydrostatic
(or end of liner)	Max.	96 PSIG	661 kPa	80% hydrostatic
		180 PSIG	1240 kPa	150% hydrostatic (not normal operating mode)
Low Pressure air				
Pressure Range	24/72/96/180 PSIG			Same as oxygen and steam
Flow	Min.	500 SCFM	849 m^3/hr	Same as oxygen estimated minimum
(per well)	Nom.	2500 SCFM	4247 m^3/hr	O_2 flux = nominal O_2 flow
	Max.	3500 SCFM	5946 m^3/hr	Operation of both modules min O_2 flow
Low pressure air				Total flow for both wells is the same as total flow per well
High pressure air flow	Min.	25 SCFM	42 m^3/hr	Minimum requirement for RCL
	Nom.	50 SCFM	85 m^3/hr	Nominal requirement for RCL
	Max.	200 SCFM	340 m^3/hr	Dewatering
		440 PSIG	3032 kPa	Lithostatic pressure +20% at linking area
Steam flow rate	Min.	739 Lb/hr	335 kg/hr	Corresponds to total
To oxygen vaporizers	Nom.	1847 Lb/hr	838 kg/hr	O_2 flow rates
	Max.	2462 lb/hr	1117 kg/hr	

*During CRIP startup and CRIP maneuvers, oxygen flow will be less than 300 SCFM.

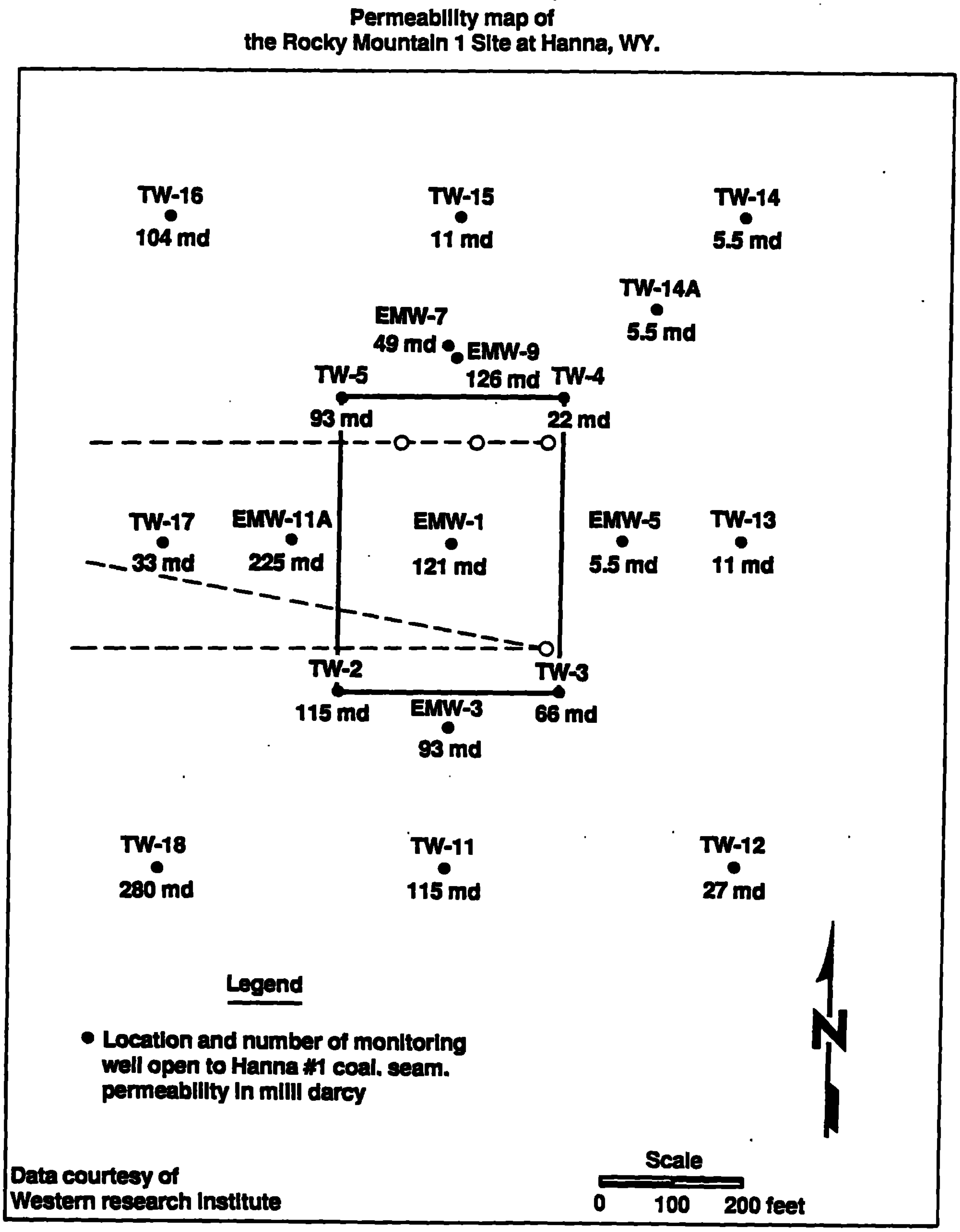

Figure 3. Permeability map of the Rocky Mountain 1 test site at Hanna, Wyoming.

The Hanna No. 1 coal is a non-swelling High Volatile C bituminous coal. The bed is about 10 m thick and approximately one-third of the coal bed consist of a carbonaceous shale containing 40 to 75 percent ash. The average heating value for the coal is 8490 Btu/lb or 4717 kcal/kgm. The average proximate and ultimate analysis is given in Table 4. The average lithology for the site is shown in Figure 4.

Table 5
Rocky Mountain 1 Coal Analysis

As Received				MAF			
Proximate		Ultimate		Proximate		Ultimate	
	%		%		%		%
Water	8.8	C	49.3			C	72.6
Ash	27.3	H	2.8			H	4.1
Volatile	32.0	N	1.2	Volatile	50.1	N	1.8
Fixed C	31.9	S	0.7	Fixed C		S	1.3
HV 8643 Btu/lb, 4802 kC/kgm				HV 13519 Btu/lb, 7511 kC/kgm			

The site appears to be quite satisfactory for underground coal gasification. The seam is obviously wetter than one would like but almost all of the water appears to be in-seam water, which is not likely to be as detrimental to the process as water in the roof of the seam.

The drilling program has been started and the surface plant construction is still on schedule. We hope to ignite the burn in September or October of this year and complete the test by early next year. Burn cavity water cleanup will start as soon after the test is completed as is feasible.

Future Activities

The DOE Program

Evaluation and modeling based on the results of Rocky Mountain 1 will continue as part of the DOE program in the following years. If there is sufficient industrial interest in further joint projects with DOE in western U.S. coal, each case will be considered on its merits for DOE participation.

It is expected that the major thrust of the DOE program will be shifted to eastern bituminous coal gasification. The large resource and nearness to big industrial markets give a strong impetus to this research. Although the U.S. coals are only about one-third as deep the other characteristics are similar to the European situation. The thin seams and swelling coal make this resource a difficult challenge. It is not clear at this time that the coals can be gasified economically and much research remains to be done.

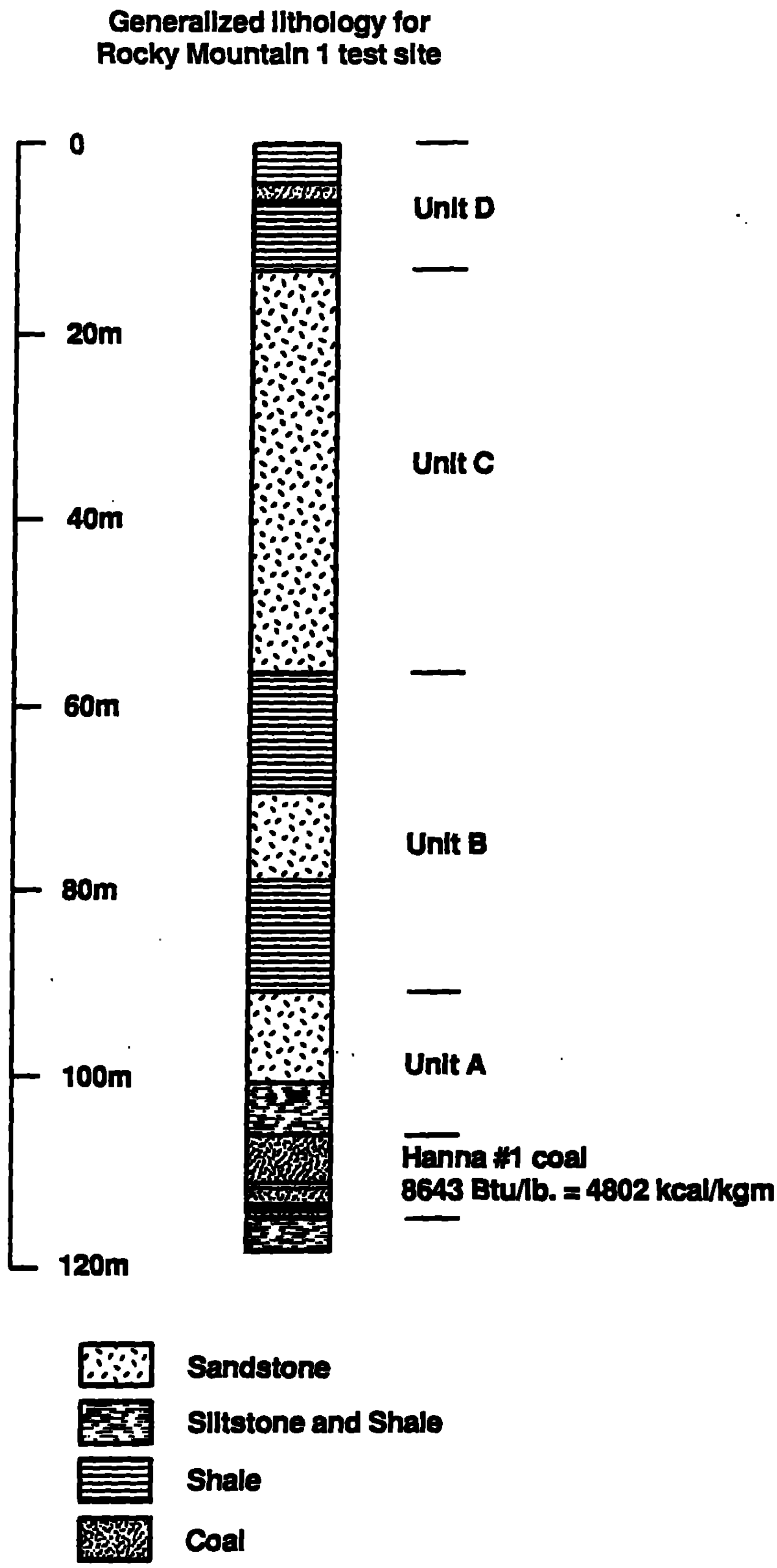

Figure 4. Rocky Mountain 1 test site generalized lithology.

Industry-Government Programs

A proposal submitted by Energy International has been accepted for cofunding under the recently enacted "clean coal" law. The proposed UCG clean fuels proof of concept project is a key element in a development program that will result in a commercial facility, west of Rawlins, Wyoming, ultimately producing 4000 barrels per day of liquids and 60 million standard cubic feet of substitute natural gas. The final commercial plant will utilize underground coal gasification to produce the synthesis gas feedstock for conversion to distillates. The four-year project will provide the additional process economics for environmental data required to reach the commercialization decision.

During the proof of concept demonstration program two UCG modules will be operated in parallel until one module is completely consumed and a third module is brought in line. During this period the average coal gasification rate will be 450 tons/day. The raw UCG product gas will be cleaned and converted into synthesis gas as feedstock to a small commercial ammonia/urea plant producing 400-500 tons of urea per day. The UCG proof of concept facility will continue to operate subsequent to the proof of concept operation to provide feedstock for a small commercial plant.

Industry Programs

Coal leases in the state of Wyoming owned by AMOCO are being considered by that company for possible use as underground coal gasification sites. They have started a long term program of environmental monitoring on these lands as a prelude to applying for permits to construct facilities. They have made no public commitment to continue the program but they are actively studying the pros and cons of the problem.

Basic Resources, a subsidiary of Texas Utilities Corp., had started plans for a pilot plant gasifier to provide electricity. This design was based on the work that they had done gasifying Texas lignite seams. This project was almost ready to start construction when it was shut down because of the changing economics due to the drop in the oil prices.

Conclusion

In conclusion, the U.S. program in underground coal gasification over the next few years will most likely continue to be moderately active, with the activity shifting more and more to the private sector of the economy in the western half of the country. The DOE program will continue in its supporting role with its activities shifting more to the eastern U.S. coals.

We have progressed a long way in the past 14 years. We have shown that underground coal gasification is not only technically feasible but that it may be economically feasible in certain cases right now. Certainly, as world energy prices rise in the future UCG will play a larger and larger role.

References

1. Dowd, J.J., Elder, J.L., Capp, J.P. and Cohen, P., Experiment in Underground Gasification of Coal, Gorgas, Ala., R.I.4164, Bureau of Mines, U.S. Department of the Interior, August 1947.

2. Elder, J.L., Graham, H.G., Capp, J.P. and Eddy, W.H., The Underground Gasification of Coal, The Military Engineer, Vol. XLIII, pp 398-401, November 1951.

3. Morgantown Energy Technology Center, Hanna, Wyoming Underground Coal Gasification Data Base, Vol. 2: The Hanna I Field Test Research Report, DOE/METC-85/2012, August 1985.

4. Morgantown Energy Technology Center, Hanna, Wyoming Underground Coal Gasification Data Base, Vol. 3: The Hanna II, Phase I Field Test Research Report, DOE/METC-85/2013 August 1985.

5. Morgantown Energy Technology Center, Hanna, Wyoming Underground Coal Gasification Data Base, Vol. 4: The Hanna II, Phases II and III Field Test Research Report, DOE/METC-85/2014, August 1985.

6. 5: The Hanna III Field Test Research Report, DOE/METC-85/2015, August 1985.

7. Hill, R.W. and Thorsness, C.B., Results from an In Situ Coal Gasification Experiment Involving Explosive Fracturing: Hoe Creek No. 1, Lawrence Livermore National Laboratory, Livermore, Calif., UCRL-52229 (1977).

8. Grant, J.F. and Fernbacher, J.M., Tennessee Colony Steam-Oxygen In Situ Lignite Gasification Test: Proc. Fifth Underground Coal Conversion Symposium, Alexandria, VA, CONF 790630, 109-117, 1979.

9. Brimhall, R.M., Results and Postburn Evaluation of TAMU's 1980 UCG Field Test in East Texas Lignite, Rockdale Site, Proc. of the 8th UCG Symposium, Keystone, CO, SAND 82-2355, August 1982.

10. Davis, G.E., and Beach, L.R., ARCO's UCG Program, p 89, Proc. of the 7th UCG Symposium, Fallen Leaf Lake, CA, CONF-810923 September 1981.

11. Singleton, A.H., Noll, W.L., and Allen, J.M., Summary Report of the Rawlins Test 1 for Gasification of Steeply Dipping Coal Beds, p 30, Proc. of the 6th UCG Symposium, Afton, OK, July 1980.

12. Davis, B.E., Ahner, P.F., Covell, J. and Singleton, A., Status of the Rawlins UCG-SDB Program, pp 205-212, Proc. 8th Underground Coal Conversion Symposium, Keystone, CO, August 1982.

13. Martin, T.W. and Liberatore, A. J., A Successful Underground Coal Gasification Field Test in a Thin Seam, Swelling Eastern Bituminous Coal, p 28, Proc. of the 6th UCG Symposium, Afton, OK, July 1980.

14. Morgantown Energy Technology Center, Hanna, Wyoming Underground Coal Gasification Data Base, Vol. 6: The Hanna IV A and IV B Field Test Research Report, DOE/METC-85/2016, August 1985.

15. Thorsness, C.B., Cena, R.J., Aiman, Hill, R.W., and Stephens, D. R., Hoe Creek No. 2 Underground Coal Gasification Experiment with Air and Steam/Oxygen Injection Periods, SPE paper 7512, presented at 53rd Annual AIME Meeting, 1978, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-80921, 1978.

16. Aiman, W.R., Cena, R.J., Hill, R.W., Thorsness, C.B., and Stephens, D.R., Highlights of the LLNL Hoe Creek No. 3 Underground Coal Gasification Experiment, Lawrence Livermore National Laboratory, Livermore, CA , UCRL-83768, 1980.

17. Thorsness, C.B. and Hill, R.W., The Large Block Tests, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-87611, 1982.

18. Cena, R.J. Hill, R.W., Stephens, D.R. and Thorsness C.B., The Centralia Partial Seam CRIP Underground Coal Gasification Experiment, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-91252, 1984.

19. Martin, G. and Davis, B., Rocky Mountain 1 underground Coal Gasification Test, p 96, Proc. of the 12th UCG symposium, Saarbrucken, Germany, DOE/FE/60922-H1, August 1986.

20. Hill, R.W. and Shannon, M.J., The Controlled Retracting Injection Point (CRIP) System: A Modified Stream Method for In Situ Coal Gasification, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-85852, 1981.

21. Youngberg, A.D. et al., Postburn Evaluation for Hanna II, Phases 2 and 3 Underground Coal Gasification Experiments, Hanna, Wyoming, DOE/FE/60177-1524, December 1983.,