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INSTRUMENTATION AND PROCESS CONTROL DEVELOPMENT FOR
IN SITU COAL GASIFICATION
QUARTERLY REPORT: APRIL THROUGH JUNE 1980

ROBERT E. GLASS, EDITOR

Prepared by Sandia Laboratories, Albuquerque, New Mexico 87185
and Livermore, California 94550 for the United States Department of
Energy under Contract DE-AC04-76DP00789.

OCTOBER 1980

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INSTRUMENTATION AND PROCESS CONTROL DEVELOPMENT FOR
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Quarterly Report: April through June 1980

Edited by: Robert E. Glass
Thermal Processes Division
Sandia National Laboratories
Albuquerque, NM 87185

Abstract

This report discusses the results of modeling efforts by Sandia National Laboratories in in situ coal gasification. The main areas addressed are (1) flow characteristics and (2) initial cavity growth. The flow characteristics problem has been addressed using both a single phase finite element model and a two phase finite difference model. The initial cavity growth problem has been addressed using a finite element structural model. These models are useful for providing insight into the processes and for determining the characteristics needed to insure successful in situ coal gasification.

Also to be discussed is the development of the controlled source audio magnetotelluric (CSAMT) electromagnetic geophysical prospecting technique. This technique is being evaluated for use in mapping in situ processes. The application discussed is the LETC tar sands project near Vernal, Utah.

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I. INTRODUCTION AND SUMMARY

This report covers the twenty-second quarter of Sandia National Laboratories program on Instrumentation and Process Control Development for In Situ Coal Gasification. This report summarizes program activities conducted between April 1 and June 30, 1980, in support of the DOE Underground Coal Gasification Program.

The successful development of any in situ fossil energy technology will require a thorough understanding of the controlling mechanisms of the in situ process. The lack of this technical understanding has been a major impediment to development of the positive process control necessary to the efficient and economical utilization of the available resources. The Sandia program for Instrumentation and Process Control Development directly addresses this factor.

The overall objectives of the program are: (1) to evaluate instrumentation techniques as they apply to in situ coal gasification, (2) to obtain diagnostic information on the chemical and physical mechanisms associated with this remote process in order to further its understanding, (3) to develop and evaluate remote monitoring techniques and establish their correlation with the process, (4) to develop analytical models for the purpose of process identification, instrumentation development and design, and (5) to develop a process control system utilizing remote monitoring techniques to maximize the recovery of energy by in situ coal gasification. Activities during this quarter contributing to these objectives will be described in this report.

Analysis of the Hanna IV-B thermal data raised questions concerning the fundamental controlling mechanisms in in situ coal gasification. Two of the concerns center on (1) the behavior of the reservoir with respect to varying permeability zones and (2) mechanisms of initial cavity growth during forward gasification. These concerns have been addressed by developing models to examine (1) the effects of flow characteristics and (2) changes in mechanical properties induced by temperature variation. The flow characteristics are examined using two programs. The first of these is a single phase, two dimensional model using the finite element program ADINAT. This program was used to investigate the effect of permeability variations on the air flow

patterns in a porous media such as coal. The second model is a two phase, two dimensional model based on the equations of flow through porous media. The results of both of the models are indicative of the importance of varying permeability layers and anisotropic permeabilities to the flow patterns in a coal seam.

The problem of temperature dependent mechanical properties is being examined using the finite element programs ADINA and ADINAT. The results of this model have demonstrated the important role temperatures play in determining the in situ stresses and the resulting mechanical failure (cracking or yielding).

In the area of instrumentation evaluation, the controlled source audio magnetotelluric (CSAMT) electromagnetic geophysical prospecting technique is being investigated. Data has been taken at the Laramie Energy Technology Center (LETC) tar sand steam-drive oil recovery project. Model calculations will be done to assess the resolution and the expected responses for the CSAMT technique.

The above accomplishments, while developed with the in situ coal process in mind, are also applicable to all in situ processes. As such, results from this program should have direct application to the development of in situ combustion recovery techniques for other fossil energy resources such as oil shale, tar sands, and petroleum.

II. MODELING

(R. E. Glass, 4737)

A. Reservoir Models

Introduction

As has been discussed previously,¹ the results of the Hanna IV tests raised questions concerning the fundamental controlling mechanisms involved in in situ coal gasification. Sandia National Laboratories is presently developing models to address these concerns.

The first models to be discussed are those dealing with the flow characteristics of the seam. This problem was attacked in two ways. The first was to use a finite element program to examine the effects of

varying permeability in single phase, two dimensional flow. The second and more complex method was to develop a two phase, two dimensional reservoir model.

The Single Phase Model

A single phase model was developed in order to provide an idea of the effects of varying permeability as well as for use as a special case check for the reservoir model. If the fluid is assumed to be an ideal gas, the governing equation for single phase flow through a porous media is given by²

$$\nabla \cdot \left(\frac{TKp\Delta p}{\mu} \right) = \frac{T\partial(\phi p)}{\partial t} \quad (1)$$

where

K = permeability
T = seam thickness
t = time
p = pressure
 ϕ = porosity
 μ = viscosity.

Assuming T, ϕ and μ are constant, this reduces to

$$\nabla \cdot (Kp \Delta p) = \mu \phi \frac{\partial p}{\partial t} \quad (2)$$

This form of the equation permits the use of the finite element program ADINAT³ which was written to solve the following equation:

$$\nabla \cdot \left(k(\theta) \nabla \theta \right) = C \frac{\partial \theta}{\partial t} \quad (3)$$

Equation 2 is equivalent to equation 3 when $p = \theta$, $Kp = k(\theta)$ and $\mu \phi = C$.

Results

The model was run with a high permeability region between 5 and 6 meters in the seam. The seam permeability, k_0 , was assumed to be 63

millidarcies⁴ and the high permeability region k , was assigned values of 1, 2, 5, 10 and 20 times the seam permeability. Figure 1 shows the results of the runs for $k = k_o$ and $k = 5k_o$. The injection well ($R = 100.5$ m) pressure is 1.04×10^6 Pa and the production well ($R = 131.5$ m) pressure is 1×10^5 Pa. Throughout the rest of the seam the initial pressure is 1×10^6 Pa. The figure shows the pressure distribution after one day when steady state has been achieved. The dashed lines show the pressure distribution with the high permeability zone and the solid line is for the uniform permeability case. Note that midway between wells the pressures are essentially equal, but since the flow rate is controlled by Darcy's equation,

$$q = \frac{-kA}{\mu} \frac{\partial p}{\partial x} \quad (4)$$

where

q = flow rate

A = cross sectional area,

the flow in the high permeability band will be essentially five times the flow in the rest of the seam. As can be seen near the injection well, there is a greater vertical pressure gradient with the high permeability than would exist in a uniform seam. This allows a significant amount

Figure 1. Pressure distribution with and without a high permeability zone. The pressures are in Pascals: $A = 3 \times 10^5$, $B = 4 \times 10^5$, $C = 6 \times 10^5$, $D = 6 \times 10^5$, $E = 7 \times 10^5$, $F = 8 \times 10^5$, $G = 9 \times 10^5$, and $H = 1 \times 10^6$.

of the air to reach the high permeability zone within 5 meters of the injection well. This is a possible explanation for the thermal response seen high in the seam at the Hanna IV-B test in the neighborhood of the injection well.

Two-Phase Model

While the single phase model yields useful insight into the effects of high permeability zones in the flow, the fact that most coal seams have high water content necessitates looking at two-phase flow. To accomplish this, a two phase, two dimensional model was developed after Blair and Weinaug⁵ and Peaceman² as discussed in a previous quarterly¹.

The program, when developed, exhibited problems with material balance calculations as the production well was depleted of air. This problem has been corrected by using specified pressures at the injection and production wells.

An additional problem encountered was the large amount of storage required. For a sample 100 node problem, the main matrix contained 40,000 elements. This problem was eliminated by storing only the nonzero elements which reduced storage requirements by 95% and additionally reduced run time by 70%.

Results

These improvements have yielded a working reservoir model, which will be used to investigate the effects of anisotropic permeability on flow patterns. The uses are twofold: (1) to predict the permeability structures most likely to yield successful in situ gasification and (2) to correlate with existing data in an attempt to understand some of the results obtained to date.

The results of a sample run are given in Table I. The reservoir is considered to be bounded by impermeable sides with phase pressures specified at injection and production wells. The data for mid seam flows are given in the table. During day 1 the air had a tendency to rise to the top of the seam, whereas by day 10 with the passage of the air front the flow was greater by a factor of 3 and essentially horizontal. The pressure drop for this run was 80,000 Pa.

TABLE I: MID SEAM AIR FLOWS

<u>HEIGHT (m)</u>	<u>VELOCITY ($\text{ms}^{-1} \times 10^5$)</u>		<u>FLOW ANGLE FROM HORIZONTAL</u>	
			<u>(RADIANs)</u>	
	DAY 1	DAY 10	DAY 1	DAY 10
0	.051	.135	.014	.095
1	.050	.133	.023	.096
2	.047	.133	.066	.098
3	.044	.134	.156	.097
4	.040	.133	.265	.097
5	.035	.131	.350	.102
6	.031	.130	.392	.112
7	.028	.132	.390	.118
8	.026	.135	.344	.112
9	.024	.135	.268	.098
10	.023	.139	.224	.091

B. Structural Model

The other major modeling activity is in the area of mechanical behavior of the coal with emphasis on charges occurring due to imposed temperature distributions. This investigation is being done using the finite element codes ADINA⁶ and ADINAT.³ In this scheme ADINAT is used to generate the temperature distribution which is then used by the structural program ADINA, to yield the stress distribution. This in turn will aid in predicting the direction and location of enhanced permeability zones and cavity formation.

The results are shown in Figure 2. The graphs depict only the immediate vicinity of the cavern. The seam is axisymmetric about the z-axis with a cylindrical cavern 1 m in radius and 1 m deep. The seam is 10 m deep and has a radius about the z-axis of 100 m. The seam sits on a bedrock seam 60 m thick. Initially the seam is being compressed by a lithostatic pressure of 10^6 Pa and the walls of the cavern are at 1000°C with the rest of the seam at 0°C . The results shown in the figure are for conditions 1 hour later. Figure 2a shows the temperature distribution given a thermal conductivity of $0.2086 \text{ Wm}^{-1}\text{K}^{-1}$ and a product of specific heat and density of $1513 \text{ Jm}^{-3}\text{K}^{-1}$. Figures 2b, 2c and 2d show the principal stress distributions corresponding to the coefficients of

Figure 2. Temperature and stress distributions resulting from the conduction of heat away from 1000 C cavern walls. For the stress contours:
A = -1.5×10^7 Pa, B = -1×10^7 Pa, C = -0.6×10^7 Pa, D = 0.,
E = 0.4×10^7 Pa, F = 0.8×10^7 Pa, G = 1.6×10^7 Pa, H = 2.4×10^7 Pa.

thermal expansion, α , of 5×10^{-6} , -5×10^{-6} and $0.C^{-1}$. As expected the positive coefficient has compressive stresses surrounding the cavern, whereas the negative coefficient (shrinking coal) has tensile stresses.

The results discussed above were for an isotropic thermo-elastic model. Future work will be directed at using a thermo-elastic perfectly plastic model with various temperature dependent yield points to more realistically model the seam.

III. USE OF THE CSAMT TECHNIQUE FOR PROCESS MAPPING (L. C. Bartel, 4737)

The controlled source audio magnetotelluric (CSAMT) electromagnetic geophysical prospecting technique is being evaluated for use to map underground energy recovery processes. The CSAMT technique is an electromagnetic (em) induction technique where the primary em field is produced by a long dipole grounded at both ends with the transmitter located at the center. A receiving antenna measures the primary plus secondary electric and magnetic fields. The resistivity is proportional to the square of the ratio of the electric field to the magnetic field. For the CSAMT system used, the electric field (E_x) is determined by measuring the voltage between two points on the earth using porous $CuSO_4$ filled pots and the magnetic field (H_y) by a ferrite wire wound coil. E_x is parallel to and H_y is perpendicular to the transmitting antenna. Soundings are made by varying the frequency from 4 to 2048 Hz.

When measurements of the electric and magnetic fields are made at distances of over three skin depths from the transmitting antenna, the apparent resistivity is given by

$$\rho_a = \frac{1.26 \times 10^5}{f} \left(\frac{E_x}{H_y} \right)^2, \quad (5)$$

where E_x is the electric field in volts/metre, H_y is the magnetic field in volts/amp, f is the frequency, and ρ_a is the apparent resistivity in ohm-metres. The skin depth δ in metres is given by

$$\delta = 503 \sqrt{\rho_a / f} \quad (6)$$

Data taken at distances greater than 36 are called far field data and ρ_a is given by Eq. 5. Data taken distances less than 36 are called near field data and for the near field data the "true" ρ_a is less than that calculated using Eq. (5). Near field data can be approximately corrected to yield the correct apparent resistivity.

Even though the near field resistivity values do not represent the "true" apparent resistivity values, near field resistivity data can be used to delineate subsurface objects if there are sufficient resistivity contrasts.

The CSAMT technique is being evaluated by Sandia at the LETC tar sand, steam-drive, oil recovery project near Vernal, UT. During a steam-drive (or fireflood) enhanced oil recovery (EOR) process, the heated region will have a decreased resistivity because of the presence of hot steam and heated groundwaters. The hot carbon associated with a fireflood will have a very low resistivity. This resistivity contrast should affect the apparent resistivity measured at the surface by the CSAMT technique.

As an example, Figure 4 shows apparent resistivity contours for measurements taken at the surface using the CSAMT technique with a frequency of 4HZ. The 4HZ data are near field data so the measured values of apparent resistivity are greater than the actual apparent resistivity values. There is a resistivity low surrounding the steam injection well (I1) and this resistivity low encompasses a production well (P7) and extends to the lower left-hand side of the figure which is the down-dip direction. At the time of these measurements oil was being produced from well P7 and water and oil from well P8. In general, the resistivity low areas correspond to the oil production history for this project.

It appears that the CSAMT technique can be used to map steam-drive EOR processes. In addition, it is speculated that this technique can be used to map UCG processes because of similar resistivity contrasts between the process area and host coal seam and surrounding strata.

4Hz

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REFERENCES

1. Glass, R. E. (Editor), "Instrumentation and Process Control Development in In Situ Coal Gasification Quarterly Report: December 1979 Through March 1980," Sandia National Laboratories Report SAND80-1025.
2. Peaceman, D. W., Fundamentals of Numerical Reservoir Stimulation, Elsevier, 1977.
3. Klaus-Jurgen Bathe, "ADINAT a Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis of Temperature," May 1977 (Rev. Dec. 1978) Massachusetts Institute of Technology, Rept. 82448-5.
4. Fulton, D. F., and Reznik, A. A., "The Measurement of the Flow Pressure Relationships of Certain Coals Pertaining to Underground Coal Gasification," Final Report September 1976 - November 1977, Contract No. EY-76-5-02-4129.
5. Blair, P. M., and Weinaug, C. R., "Solution of Two-Phase Flow Problems Using Implicit Difference Equations," SPE Journal, December 1969.
6. Klaus-Jürgen Bathe, "ADINA A Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis," September 1975 (Rev. December 1978) Massachusetts Institute of Technology, Rept. 82448-1.

PUBLICATIONS, PRESENTATIONS, AND OTHER COMMUNICATIONS

A. Publications

1. R. E. Glass (Editor) "Instrumentation and Process Control Development for In Situ Coal Gasification Quarterly Report: December 1979 through March 1980," Sandia National Laboratories Report SAND80-1025.

B. Presentations

C. Other Communications

1. L. C. Bartel gave a briefing on the status of the UCG site characterization work in Washington State to representatives from WIDCO, Washington Water Power, PP & L, State of Washington, LLNL, as well as SNL in Centralia, WA, on April 24, 1980. B. E. Bader and S. L. Love also attended.
2. B. E. Bader and S. L. Love attended a coal management meeting in Laramie, WY, on May 7, 1980.
3. B. E. Bader, L. C. Bartel, T. C. Dobecki, and P. J. Hommert met with representatives from Mobil Research and Development Corporation and Mobil Oil Corporation to brief them on the Washington State assessment and discuss possible cooperative work on May 9, 1980.

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