NUMERICAL CODE COMPARISON PROJECT- A NECESSARY STEP TOWARDS CONFIDENCE IN GEOTHERMAL RESERVOIR SIMULATORS

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Numerous computer codes capable of solving the general geothermal reservoir engineering problem involving mutiphase flow of fluid and heat have been developed over the past several years. At the present time, the validity of results obtained using these simulators to model the performance and predict the response of real geothermal systems is the subject of concern both to those involved in developing and managing geothermal resources and to those involved with financing such enterprises. Do these codes accurately simulate the physical processes believed to be important? Can simulator users develop realistic conceptual models and appropriate values of input parameters to insure that numerical models of particular reservoirs yield valid results?

Experience gained in several attempts to model the Wairakei geothermal reservoir in New Zealand (Mercer and Faust 1979; Garg, Rice, and Pritchett, 1979) demonstrates that problems involved in applying these codes to real systems are significant (Sorey and Fradkin, 1979; Donaldson and Sorey, 1979), and that results obtained from various models can be quite different. A necessary first step in resolving such differences and in evaluating the usefulness of numerical simulators for geothermal reservoir analysis is the comparison of simulator results for a set of well-specified problems involving processes applicable in reservoir analysis.

Under the direction of DOE's Geothermal Reservoir Engineering Management Program (GREMP), a set of six test problems has been developed in an attempt to meet this need. The problem set covers a range of reservoir situations including single- and two-phase flow under 1, 2, and 3 dimensional conditions. Each problem has been test run to insure that the parameter specifications will yield workable solutions, and in several cases analytical solutions are available for comparison. Brief descriptions of the problems are given below in each problem, the desired grid and time-step sizes were specified to minimize differences in results due to numerical discretization.

A Request for Proposals for the Code Comparison Project was issued in June, 1980, through DOE's San Francisco Operations Office. Proposals were accepted up until July 7, 1980 from any group possesing a numerical simulator capable of solving a minimum of two of the test problems. Four contracts were awarded effective September 1, 1980. Selection of proposals was based on technical merit and cost. While the number of groups participating was not large, the codes involved are felt to be representative of the range of numerical simulators currently being applied to geothermal reservoir analysis. In one case, a non-code developer will use a commercially available code to run five of the six test problems. Participating groups include Intercomp, Geotrans, Science Systems and Software, and Stanford University.

The basic code capabilities deemed necessary in this project included simulation of single and two-phase flow of pure water and steam in one and two dimensions. Many of the codes posses additional capabilities which may be needed in specific reservoir situations including, for example, simulation of subsidence, noncondensible gas flow, and fluids with high dissolved solids content. Details on the solution techniques and special simulator capabilities for most of the well-documented codes in use today are given by Pinder (1979) and Pritchett (1979).

The term of each contract was three months, including participation in the 1980 Stanford Workshop. Two and one half months were allotted for completion of the problems proposed for solution by each group and delivery of specified results to DOE. Preliminary comparisons and evaluations of results for each problem will be presented at the Workshop by the individules who developed the test problems. A final report on the Code Comparison Project will be issued in early 1981.

Problem 1: 1-D Avdonin Solution

This problem involves radial flow of fluid and heat in a liquid-saturated porous media. Fluid flow is approximately steady-state and is transported by conduction and convection. Water at $160^{0}C$ is injected into a reservoir initially at $170^{0}C$, and flow occurs from a well at zero radius to an outer boundary at 1000 m. Fluid properties are held constant for comparison with the analytical solution of Avdonin (1964). Output specifications include temperature versus radial distance for a fixed time and temperature versus time at a fixed radius.

Problem 2: 1-D Well-Test Analysis

This problem involves a set of four transient well-test cases. Each case treats radial flow to a constant-discharge line sink in homogeneous porous media. In case A the fluid is single-phase liquid, in case B the fluid is a two-phase mixture with both steam and water mobile, and in case C the fluid changes from compressed liquid to a two-phase mixture as the flash front moves away from the well. An additional problem under case B conditions involves constant discharge from a one-node reservoir. For each case either an exact analytical solution or an accurate semi-analytical solution is available for comparison with numerical results. Solutions will consist of pressure, saturation, and flowing enthalpy changes as functions of time/distance squared. Relative permeability functions based on the Corey equations are to be used throughout under two-phase conditions.

Problem 3: 2-D Flow to a Well in Fracture/Block Media

This problem represents a simplification of the general problem of well testing in fractured reservoirs. A well producing at constant discharge is open to a horizontal fracture of large lateral extent. Radial flow in the fracture (treated as a high permeability porous layer) induces vertical flow from an adjacent low permeability block of finite vertical dimension. For application to vapor-dominated reservoirs, only the steam phase is mobile. Simulations with and without a boiling liquid phase in the block are to be included. Output specifications consist of well-face pressure and pressure and saturation at one point in the block as functions of time.

Problem 4: Expanding Two-phase System with Drainage

This problem involves one-dimensional vertical flow under both single and two-phase conditions. An initially hydrostatic column of liquid is disturbed by mass withdrawl at the bottom. Boiling occurs near the top of the column and extends downward. Constant pressure/temperature specifications at the top of the column result in inflow of cold water at this boundary. The permeability distribution is non-uniform and relative permeability functions based on the Corey equations are used in the two-phase region. In principal, this problem simulates some of the dominant features in the response of a liquid-dominated reservoir to production from depth. The desired output includes pressure, temperature, and saturation variations at several depths, the discharge enthalpy history of the produced fluid, and recharge rates and cumulative recharge at the surface.

Problem 5: Flow in a 2-D Areal Reservoir

This problem involves single and two-phase flow in a two-dimensional horizontal reservoir. Mass is produced at one point in the reservoir and recharge is induced over one of the lateral boundaries. The fluid is initially all liquid with a non-uniform temperature distribution (160^{o}C-240^{o}C). Two cases for the production strategy are to be simulated. In cases A and B, a well close to one corner of the field produces at constant mass for 10 years. In case B, an injection well is added near another corner of the field which injects 80^{o}C water at constant rate after 1 year of production.

Output requirements include variations with time of pressure and temperature at selected points, discharge enthalpy history in the production well, and variations with time in total mass of steam in the reservoir. In addition, for those simulators with subgrid or near-well models, variations in the sandface pressure and saturation at the production well and sandface pressure at the injection well are to be given.

Problem 6: Flow in a 3-D Reservoir

This problem involves multi-phase flow in a three dimensional reservoir, with production from one corner grid block and constant pressure upper and lower surfaces. The fluid is initially single-phase liquid, except in one layer where an immobile steam phase exists. Initial conditions are functions of depth only, including a hydrostatic pressure distribution. The grid consists of five layers with 25 nodes in each layer. Production strategy involves a variable mass flux from one node with a total production time of 10 years. The desired output includes pressure, temperature, and saturation at selected points and the discharge enthalpy history.

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