GEOTHERMAL CONFIRMATION DRILLING PROGRAM

AGENDA

1. Meeting Objectives ------------------S. M. Prestwich
2. Management Direction ------------------C. R. Nichols
3. Environmental Generic Aspects --------S. G. Spencer/S. M. Prestwich
4. Solicitation
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EG&G Idaho

INTEROFFICE CORRESPONDENCE

date March 4, 1980

to E. G. DiBello

from D. M. Callan

subject PROPOSED USER COUPLED DRILLING PROGRAM - WELL EVALUATION GUIDELINES - DMC-4-80

Attached are preliminary notes outlining the major criteria to be considered in evaluating well tests under the subject program. These notes are presented at this time to encourage discussion with DOE-ID staff so that we may arrive at a suitable scope and format for inclusion in the solicitation documents.

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Attachment:
As stated

cc: C. A. Allen
M. R. Dolenc
D. Goldman
J. H. Ramsthaler
R. R. Stiger
Central File w/o attachment
Letter File

FORM EG&G-951
(Rev. 05-79)

USER COUPLED GEOTHERMAL DRILLING PROGRAM
WELL EVALUATION GUIDELINES

1. INTRODUCTION

These guidelines are presented to provide minimum data required for evaluation of geothermal well yields. It is assumed that the geothermal test well has been sited, drilled, constructed and developed under the guidance of a competent hydrogeologist and drilling engineer. It is further assumed that the resource being exploited is low to moderate temperature and conforms to single-phase flow behavior.

The guidelines should be considered as general, introduction to requirements only. Site and resource-specific considerations will be required dependent upon the results of drilling and local conditions.

2. EVALUATION DURING DRILLING

During the drilling and development procedures, preliminary information on the nature and behavior of fluids must be collected in order to maximize the benefits of subsequent testing. The information available during drilling will to some degree be determined by the method of drilling and in some cases will require geophysical logging techniques to obtain it. Required information includes:

2.1 location (depth and thickness) of identified fluid-bearing horizons.

2.2 estimate of fluid contribution to the borehole at each identified horizon.

2.3 representative sample of fluid at each identified horizon.

2.4 measured head or flow at each identified horizon.

2.5 borehole temperature and caliper survey, prior to any intermediate casing and in the completed well.

2.6 geophysical logs of open borehole if other than water used as drilling fluid. Geophysical logging suited to provide hole diameter, temperature profile, bed boundaries, porosity and depth of drilling fluid penetrations.

2.7 flowmeter log in any well with multiple horizon contribution to the borehole.

Any well development techniques such as nitrogen or air lifting or swabbing should be organized with the dual purpose of measuring fluid level response during recovery in order to estimate yield potential.

PRELIMINARY DRAFT

3. TEST OBJECTIVES

The primary objective in well testing is to stress the producing reservoir sufficiently to predict the well's performance under sustained withdrawals. In order to select a suitable flow or pumping rate at which to test the well and evaluate the efficiency of the well, pulse tests at a range of rates are required. A sustained test is further required to identify possible reservoir boundary influences on well performance and to extend confidence in the quality and temperature of the resource with long-term production.

Appropriate analytical techniques must be applied to the test data in order to estimate the hydraulic properties of the wellbore and reservoir and predict the well's behavior for a period of five years.

Many geothermal reservoirs are comprised of fractured competent rock. Hydraulically this type of reservoir does not conform to the assumptions demanded by standard analytical methods. For this reason it is recommended that well tests in fracture-flow media should preferably be carried out at or above the rate of which the well might be used. Straight-line extrapolations to extended time are probably the most reliable means of predicting future well behavior in fractured rock reservoirs.

In geothermal well evaluations the duration of testing must be sufficient to exceed temporally transient thermal influences.

4. ORGANIZATION OF WELL TESTS

There are several considerations which must be recognized and organized prior to conducting geothermal well tests. These include:

4.1 Recognition and monitoring of all sources which may be hydraulically interfered with during testing. These include natural discharges or adjacent hot or cold wells. It is essential to understand any trends or fluctuations in fluid levels in adjacent sources for a period of one week prior to testing. A confident data baseline is required to establish whether interference has occured during testing and answer any litigation which might arise.

4.2 Recognition and monitoring of natural external influences on fluid level (piezometric) surfaces such as barometric and tidal changes or possibly railway activity. One week of monitoring stabilized fluid levels will reveal such influences.

4.3 The test well must be permitted to reach stable initial conditions prior to testing.

4.4 Disposal of geothermal fluids must be arranged before testing and adequate measures taken to conduct fluids to an environmentally acceptable point of discharge.

4.5 A temperature survey should be run in the well immediately prior to testing.

4.6 If the well is to be pumped, rather than free-flowed pump selection criteria should include:

a) thermally adequate equipment

b) sufficient drop-pipe to represent reasonable lifting costs to the user.

5. PULSE TESTING PROCEDURES

All well tests must include short pulse tests of a range of rates to estimate the probable maximum rate at which the well can be flowed or pumped and provide indication of temperature and quality stability at several rates. Pulses should be run at progressively higher rates and the well permitted to recover between rates.

5.1 Duration of Pulses

Each pulse should be minimum three hours duration with minimum three hours recovery or to initial piezometric conditions. Recovery period should be equivalent to the duration of pulse. All pulses must be of equivalent duration.

5.2 Required Pulse Test Data

It is forseen that many well tests may rely on wellhead measurements if suitable bottom-hole pressure and temperature instrumentation is not readily available. Transient, temperature-induced changes in fluid density and viscosity profoundly influence measurements of the piezometric surface at wellhead. For this reason, wellhead measurements must include careful continuous temperature records and pulse test duration should be sufficient to reach quasi-equilibrium temperatures. The parameters measured must include:

5.2.1 Flow Rate: The flow rate must be capable of being controlled by means of a suitable valve in the discharge line. Flow rate must be measured carefully and continuously by means of a circular orifice weir or similar device acceptable to DOE.

5.2.2 Fluid(piezometric) Level Changes: Measurements of well head pressure or fluid level must be recorded with a frequency of at least 20 measurements distributed per log cycle of time in minutes. Such measurements should be made during both drawdown and recovery segments of each test.

5.2.3 Temperature: Wellhead temperatures must be recorded during both drawdown and recovery segments of each test. A continuous record of temperature fluctuations is preferable but in the event that manual readings are necessary, these should be of similar frequency to the fluid (piezometric) level observations.

5.2.4 Quality: Samples of the discharged fluid must be collected at least as frequently as the beginning, middle and end of any test period. In-line measurement of specific conductance is recommended with sampling frequency of at least once each 24 hours. Parameters analyzed will be site specific but should include geothermometric indicators.

5.3 Analysis of Pulse Test Data

The pulse data should be analyzed by techniques appropriate to the acceptable assumptions of reservoir behavior. Data should be corrected where feasible for temperature and external influences. The analysis should provide:

a) the most appropriate rate at which to carry out a sustained well test together with the reasoning for this decision.
b) estimates of specific capacity of the well for a stated time.
c) estimates of the relative efficiency of the well over the range of rates pulse tested.
d) estimates of well losses.

6. SUSTAINED TESTING PROCEDURES

The sustained test must be designed to provide enough information to permit reasonably confident prediction of the well's behavior for a period of five years. The constant-rate type of test is recommended as most appropriate for the low to moderate temperature geothermal resource.

6.1 Duration of Sustained Test

The two major criteria influencing the duration of a sustained test are to extend to quasi-equilibrium temperature conditions and to indicate the presence of reservoir inhomogeneities or boundaries. To some degree the selection of duration is influenced by the well's performance during the test. An arbitrary period of five days is recommended as the practical minimum duration in which most boundary influences should be detected.

6.2 Required Data in Sustained Tests

The four major parameters of flow rate, fluid(piezometric) levels, temperature and quality outlined in section 5 above are also mandatory requirements in any sustained test. Similar frequency to that outlined for pulse testing should be followed both for drawdown and recovery segments of the test.

6.3 Analysis of Sustained Test Data

The assumptions made about the reservoir in selecting the most appropriate analytical method must be clearly addressed in the test analysis. If uncorrected field data is used in the test analysis it must be clearly evident that corrections are not applicable.

Calculation of any reservoir hydraulic properties used in predictive models must be clearly substantiated. In standard analytical techniques it is assumed that no further reservoir boundaries will be intersected following the period of the test. In the event that observation wells are available, any additional reservoir data must be incorporated into the predictive model.

Long term (5 year) predictions must include consideration of transient density and viscosity changes.

7. ALTERNATIVE TEST PROCEDURES

It is likely that specific situations may demand other than the procedures of pulse testing followed by a sustained constant rate test. In the event that an alternate method of well testing is proposed, the method must be shown to be both specifically applicable and sufficiently accurate to meet the objectives of long term prediction of well behavior.

Analytical techniques other than standard non-equilibrium, non-steady state flow assumptions must similarly be shown to have sufficient precedent to meet predictive objectives with equivalent confidence.

8. MEASUREMENTS & INSTRUMENTATION

Measurements of the few major parameters must be sufficiently accurate to meet the stated testing objectives. Recommended limits of accuracy are detailed below.

8.1 Flow Rate

Flow rate must be controlled within ± 3% accuracy with resolution of 0.13 lps.

8.2 Fluid (piezometric) Levels

Free fluid levels should be measured to 0.3 cm precision. Fluid pressures should be measured to 0.01 psi.

8.3 Temperatures

Mercury thermometers used for temperature measurement should be calibrated to $0.2^{O}C$ per division.

GEOTHERMAL RESOURCE AREAS 150-90°C WITH PROBABLE USERS

STATE	790 NAME + NUMBER	LOCATION / USER	MEAN RESERVOIR TEMPERATURE (°C)	MEAN RESERVOIR THERMAL ENERGY (10^{18} J ≈ 1 QUAD)
ARIZONA	#32 GILLARD H.S.	CLIFTON-MORENCI AREA	126 ± 12	1.00 ± .30
	#			
	#33 SAN SIMON WELL	SOUTH OF CLIFTON-MORENCI	135 ± 4	.75 ± .17
CALIFORNIA	ALTURAS DISTRICT	NE CALIFORNIA		
	#34 FORT BIDWELL		135 ± 17	1.08 ± .34
	#36 W. VALLEY RESERVOIR H.S.		143 ± 3	1.15 ± .32
	#37 BASSETT H.S.		98 ± 7	.74 ± .22
	#38 KELLY H.S.		118 ± 10	.93 ± .27
	#42 WENDELL-AMADEE AREA	SUSANVILLE KGRA	126 ± 7	3.2 ± 0.9
	#50 CALISTOGA H.S.	SOUTH OF THE GEYSERS	144 ± 3	2.4 ± 0.7
	#60 SLOVERN H.S.	NE OF BAKERSFIELD	106 ± 7	.82 ± 0.24
	#62 ARROWHEAD H.S.	E OF LOS ANGELES	132 ± 8	1.06 ± 0.31
	IMPERIAL VALLEY AREA:	SE CALIFORNIA		
	#63 PILGER ESTATES H.S.		105 ± 7	.81 ± 0.24
	#66 GLAMIS (E. BRAWLEY)		132 ± 14	1.05 ± 0.32
	#67 GLAMIS EAST		132 ± 14	1.57 ± 0.56
	#69 DUNES		132 ± 14	2.8 ± 0.8
COLORADO	#72 ROOTT H.S.	STEAMBOAT-CRAIG AREA	130 ± 11	1.04 ± 0.31
	GUNNISON-SALIDA DISTRICT	CENTRAL COLORADO	112 ± 10	1.68 ± 0.48
	#74 MT. PRINCETON H.S.		112 ± 10	1.68 ± 0.48
	#75 PONCHA H.S.		109 ± 7	0.84 ± 0.24
	#76 WAUNITA H.S.		141 ± 10	1.14 ± 0.33

Geothermal Resource Areas 90-150°C (cont)

State	790 Name + Number	Location/User	Mean Reservoir Temperature (°C)	Mean Reservoir Thermal Energy (10^{18} J ≈ 1 Quad)
Nevada (cont)	#165 Carlin Area	Elko-Carlin Area	96 ± 8	.73 ± 0.22
	#166 Hot Hole (Elko H.S.)	Elko Area	93 ± 7	.70 ± 0.21
New Mexico	Valles District	W of Los Alamos		
	#172 Jemez Spring		105 ± 7	.81 ± .24
	#173 Spence Spring		103 ± 15	.79 ± .26
	#176 Lightening Dock	Lordsburg Area	144 ± 13	1.16 ± .35
Oregon	#177 Mt. Hood	E of Portland	122 ± 12	.96 ± .29
	#186 Klamath Hills Area	South-Central Or.	124 ± 7	3.1 ± 1.1
	#187 Klamath Falls Area	South-Central Or.	111 ± 7	30 ± 15
	#189 Lakeview Area	South-Central Or.	150 ± 3	5.6 ± 2.0
	#191 Fisher Hot Spring	South-central Or.	114 ± 7	.89 ± .26
	#202 Little Valley Area	Vale, Or. area	127 ± 6	1.01 ± 0.29
Utah	#206 Monroe-Red Hill	SW Utah	101 ± 8	1.09 ± 0.38
	#211 NewCastle	Cedar City Area	130 ± 11	1.90 ± .91
Wyoming	#218 Auburn H.S.	Idaho-Wyo. Border	90 ± 6	.67 ± .20
				Total 540.5 ± 143.87

Geothermal Resource Areas 150-90°C (cont)

State	790 Name + Number	Location / User	Mean Reservoir Temperature (°C)	Mean Reservoir Thermal Energy (10^{18} J ≈ 1 Quad)
Colorado (cont)	#82 Splashland Well	Alamosa Area	141 ± 10	1.14 ± 0.33
Idaho	#94 Weiser Area	Western Idaho Border	130 ± 14	1.38 ± 0.55
	#95 Roystone H.S.	North of Emmett	135 ± 5	1.08 ± 0.31
	#102 Bruneau-Grandview	SW Idaho	107 ± 6	450 ± 110
	Camas District	South-Central Idaho		
	#109 Magic Reservoir		149 ± 6	1.20 ± 0.37
	#110 Worswick H.S.		94 ± 5	0.71 ± 0.20
	#111 Wardrop H.S.		97 ± 14	0.74 ± 0.25
	#112 Barron's H.S.		103 ± 7	0.79 ± 0.23
	Preston District	SE Idaho		
	#118 Maple Grove H.S.		93 ± 6	.70 ± .20
	#119 Riverdale Area		99 ± 10	.76 ± .23
	#120 Wayland		113 ± 12	.88 ± .27
	#121 Squaw		119 ± 14	.94 ± .29
Montana	#123 Broadwater	Helena Area	118 ± 8	.92 ± .27
	#126 Fairmont H.S.	West of Butte	118 ± 6	.92 ± .26
	#129 Ennis	SW Montana	129 ± 8	1.03 ± .30
Nevada	#140 Moana Area	Reno Area	116 ± 14	2.4 ± .6
	#150 Colado	Lovelock Area	97 ± 14	.73 ± .24
	#155 Golconda	East of Winnemucca	96 ± 7	.73 ± .21