GL02970

TerraTek

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J. F. KUNZE

JUN 5 1975

Action Info
R.C.S.
J.F.K.

June 3, 1975

Dr. J. Kunze
Aerojet Nuclear Company
550 Second Street
Idaho Falls, Idaho 83401

Dear Dr. Kunze:

The following is a description of the tests and a summary of the results obtained by Terra Tek, Inc. on core samples taken by the Aerojet Nuclear Company, Idaho Falls, in drilling at the Raft River geothermal well project. Tests were performed on each of the two samples to determine the permeability at *in situ* conditions. These conditions were specified and are listed in the following table:

	RRGE #2	RRGE #1
Sample Depth (feet)	4,227	4,506
Axial Stress - Vertical (psi)	4,855	5,175
Lateral Stress (psi)	3,480	3,710
Pore Pressure (psi)	1,880	2,005
Temperature (° F)	220°	210°

The lateral stress was calculated by assuming Poisson's ratio to be 0.35 at *in situ* conditions. Tests were performed on two inch diameter samples cored from the original four inch core. Specimen axes were parallel to the core axes. The tests were carried out in a two kilobar pressure vessel equipped with external heaters. All stresses and pressures were measured inside the vessel and controlled to within one percent of the *in situ* values listed in the above table. Typical temperature fluctuation is less than one degree Farenheit for the tests.

Permeability was determined via the transient pressure decay method which requires a gradient of less than five percent of the pore pressure across the samples. Distilled water was used as the pore fluid. The permeability values obtained were:

	#2	#1
Sample Depth (feet)	4,227	4,506
Permeability (millidarcies)	0.003 0.04	5
	Siltstone	Tuff

Core analysis:
$\phi \approx 18\%$
$k = 8.41$ md (oil-gas)
2.55 gm/cc

Two samples were prepared from the 4,227 foot level core because of inconsistent fractures through the rock. Both values show the rock to be tight and close grained; furthermore, the noted variation in permeability is not uncommon in such rock even without the sample intersecting fractures and flaws. To obtain an average permeability value for any formation, a minimum of five tests should be performed.

The sample taken from the 4,506 foot level has a permeability typical of tuff (usually 0.1 to 10 millidarcies).

If you have any questions regarding test procedures, equipment, results or capabilities, please feel free to call.

Sincerely,

Arfon H. Jones
Vice President

Randy R. Nielsen
Research Engineer

jt

TerraTek

J. F. KUNZE

August 20, 1975

AUG 22 1975

Action | Info

Dr. Jay Kunze
Aerojet Nuclear Company
550 Second Street
Idaho Falls, Idaho 83401

Dear Jay,

The following summarizes the test performed on the sample left at the Salt Lake City Airport last Tuesday evening, August 12. Core identification was RRGE #2, taken from about 4,372 feet. The sample taken from this rock was cored in the horizontal direction and did not intersect the crack present (this crack was not obvious until we started coring). The following summarizes the experimental results:

Axial Pressure	3265 psi	5025 psi
Lateral Pressure	3265 psi	3265 psi
Pore Pressure	1945 psi	1945 psi
Temperature	200° F	200° F
Measured Permeability	2.2 microdarcies	2.2 microdarcies

Note that when we increased the axial load (the radial direction for the core) there was no change in permeability. This has been previously observed for low differential axial loads (i.e., prior to the initiation of dilation).

Both tests were performed on a 3/4 inch diameter by 1 3/8 inch long specimen. Test conditions and tolerances are as noted in my previous letter dated June 3, 1975 with the exception the pore fluid was nitrogen.

If you have any questions regarding this test, please feel free to contact either of the undersigned.

Sincerely,

A. H. Jones
Vice President

Randy R. Nielsen
Research Engineer

AHJ/jt

TerraTek

August 2, 1976

Dr. J. Kunze
Aerojet Nuclear
550 Second Street
Idaho Falls, Idaho 83401

Dear Dr. Kunze:

The following is an account of the permeability test results for the two latest groups of samples taken from the Raft River geothermal well RRGE #3. The first group was tested in April of 1976, the second group was tested in May.

The following table summarizes the results for the first group of samples:

WELL RRGE #3

Footage and Designation	Description	Confining Pressure (psi)	Pore Pressure (psi)	Permeability (millidarcies)
3365 (3347 GL)	Tight Green Sandstone - Siltstone material	3365	1450	.04
3365 Upper	Loose green tuffaceous SS	3365	1450	3.4*
2807 2789 GL	Small grained ~~granite~~ SS	2800	1200	.25
2807 Inside	Brown shaley sandstone	2800	1200	.02

* The previously reported value of > 35 millidarcies for this sample was an air permeability. 3.4 millidarcies was obtained using water as the permeating fluid. This dramatic change is due to the swelling of the clay materials found in tuff.

Results for the second group of samples is given below:

milli = 10^{-3}
micro = 10^{-6}

WELL RRGE #3C

Footage and Rock Type	Description	Confining Pressure (psi)	Pore Pressure (psi)	Permeability* (Millidarcies) (T=70°F)	(T=220°F)
4985 Calcareous sandstone	Healed fracture	5000	2165	.035	.006
4994 Silty shale	Healed fracture	5000	2165	.001	.001
5273 Siltstone	Healed fracture	5800	2500	.025	.019
5273 Siltstone	Fracture filled with brown silt	5800	2500	.12	.044

* Please note, the values reported to you by phone were the room temperature permeabilities.

These results show that although the sample from core 4994' contained joints in the direction of flow, these joints do not allow the flow of fluid. Conversely, the relatively thick joint (on the order of .5 mm) found in the second sample from 5773' did significantly increase the flow through the sample. Note also the significant effect of temperature on the thick joint.

5273

Presently, there is no generally acepted theory as to why permeability decreases as temperature increases although this phenomenon has been observed by others (private conversation with Prof. W. F. Brace, M.I.T., 1976). Some possible explanations are as follows:

1. The addition of heat may cause significant increases in the "creep" rate of a rock sample, resulting in higher compaction during exposure to confining stresses.

2. The addition of heat may cause or contribute to the swelling of interstitial materials found within the rock matrix. Hence, the pore areas are clogged at higher temperatures.

3. The presence of hot, flowing water inside the pores may tend to remove the softer materials from the matrix, depositing them in the narrow flow channels, blocking the flow.

Any one or a combination of these effects could significantly effect permeability depending upon the rock type.

If you have questions about the results, please call. The remaining core material is being stored at Terra Tek and is available at any time.

Sincerely,

Randy R. Nielsen
Research Engineer

RRN/ps

cc: Mr. Roger Stocker
A. H. Jones

TerraTek

January 18, 1977

Mr. R. C. Stoker
Geothermal Projects
EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, Idaho 83401

Dear Roger,

Per your request of 1-6-77 (letter to Dr. Arfon Jones), total and effective porosity for the core enumerated below were determined and are enclosed. The same data was transmitted to you in our telephone conversation on 1-17-77.

	Footage	Description
RRGE-1		
1.	4,500.5'	Green tuffaceous siltstone
2.	4,518.0'	Dark gray micaceous siltstone
3.	4,687.0'	Phyllite
RRGE-2		
4.	3,728.4'	Siltstone
5.	4,223.8'	Siltstone
6.	4,227.0'	Siltstone (sealed)
7.	4,373.0'	Calcareous tuffaceous siltstone
8.	6,500.0'	Quartz monzonite
RRGE-3A		
9.	3,365.0'(lower)	Tight green sandstone
10.	3,365.0'(upper)	Loose green tuffaceous siltstone
RRGE-3C		
11.	4,994.0'	Silty shale
12.	5,273.0'	Siltstone
13.	5,550.5'	Quartzite

Dry density and grain density determinations were made on all footages and used to calculate the total porosity. The effective porosity measurements were made using domestic water as an impregnating fluid. The driving

pressure for the effective porosity testing was 750 psi (5.17 MPa). The porosities are expressed as a percent of the total volume. "As-received" density measurement was made only for the sealed core from RRGE-2 4,227.0 footage.

If I can be of further assistance in clarifying the data or procedures, please call.

Sincerely,

Dan

D. O. Enniss
Project Engineer

DOE/jlg

Enclosure

SAMPLE	WET BULK DENSITY (gm/cc)	DRY BULK DENSITY (gm/cc)	GRAIN DENSITY (gm/cc)	TOTAL POROSITY (%)	EFF. WATER POROSITY (%)
RRGE-1 4500.5'	--	1.88	2.62	28.8	28.8
4518.0'	--	2.20	2.67	17.6	14.3
4687.0'	--	2.73	2.79	2.2	0.8
RRGE-2 3728.4'	--	2.16	2.66	18.8	13.2
4223.8'	--	2.07	2.66	22.2	15.0
4227.0'	2.29	2.20	2.72	19.3	17.4
4373.0'	--	2.28	2.67	14.5	13.6
6560.0'	--	2.57	2.64	2.7	0.8
RRGE-3A (L) 3365.0'	--	1.74	2.60	33.1	11.3
(U) 3365.0'	--	1.53	2.48	38.3	34.7
RRGE-3C 4994.0'	--	2.31	2.70	14.4	9.1
5273.0'	--	1.97	2.66	25.9	23.0
5550.5'	--	2.64	2.70	2.2	1.2

TerraTek

May 19, 1977

Mr. R. C. Stoker
Geothermal Projects
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, Idaho 83401

Dear Roger:

Total porosity, effective water porosity, and water permeability tests were conducted on the following sample as per your request (letter dated April 4, 1977 to Dr. Arfon Jones).

RRGI-4 SILTY SANDSTONE 1900' G. L.

The results follow:

Wet Bulk Density	2.18	gm/cc
Dry Bulk Density	1.93	gm/cc
Grain Density	2.64	gm/cc
Total Porosity	26.5	%
Effective Water Porosity	24.5	%
Water Permeability (σ_3 = 1900 psi, 20°C)	60	Millidarcy's

The dry and grain densities were used to calculate the total porosity. The effective porosity measurement was made using water as an impregnating fluid at a driving pressure of 750 psi (5.17 MPa). Water permeability was determined for a saturated sample using the transient pressure method. Domestic water was used as the permeability fluid while the sample was confined at 1900 psi (13.1 MPa) to simulate overburden stress.

If I can be of further assistance in clarifying the data and procedures, please call.

Sincerely,

D. O. Enniss
Project Engineer

DOE:gk

TerraTek

June 21, 1977

Mr. R. C. Stoker
Geothermal Projects
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, Idaho 83401

Dear Roger:

The following cores were received from RRGI-4:

GL + 14' = KB

1.	2842.25'	-	2842.6'	Sandstone
2.	2844.08'	-	2844.7'	Sandstone - Siltstone
3.	2847.5'	-	2848'	Siltstone
4.	2850.3'	-	2850.75'	Sandstone
5.	2852.6'	-	2853.25'	Siltstone

Approximately 50% of each core was retained for our test purposes. The remainder was forwarded to Harry Covington, U.S.G.S., Denver according to your request, (Letter dated May 17, 1977 to Dr. Arfon Jones). Wet bulk density, total porosity, effective water porosity and water permeability were determined for all footages. The results are enclosed.

The wet bulk density represents the "as-received" state of the wax sealed cores. Dry and grain densities were used to calculate the total porosity. The effective porosity measurement was made using water as an impregnating fluid at a driving pressure of 750 psi (5.17 MPa). Porosity values are expressed as a percentage of the total sample volume.

Water permeability was determined for each footage using the transient pressure technique. Domestic water was used as the permeating fluid while the sample was confined at 2800 psi (19.3 MPa), 20° C to simulate over burden stresses. The samples were saturated prior to testing.

Mr. R. C. Stoker
June 21, 1977

If I can be of further assistance in clarifying the data or procedures please call.

Sincerely,

D. O. Enniss
Project Engineer

Enclosures

DOE:gjk

SAMPLE DESIGNATION	WET BULK DENSITY (gm/cc)	DRY BULK DENSITY (gm/cc)	GRAIN DENSITY (gm/cc)	TOTAL POROSITY (%)	EFF. WATER POROSITY (%)	CONFINED WATER PERMEABILITY σ_3 = 2800 psi
2842.25'	2.28	2.03	2.66	24.0	23.0	280μD
2844.08'	2.45	2.34	2.69	13.0	13.0	10μD
2847.5'	2.54	1.93	2.70	28.5	28.5	16μD
2850.3'	2.31	2.16	2.67	19.0	19.0	80μD
2852.6'	2.39	2.01	2.70	25.6	23.0	40μD