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NATURAL GAS MASSIVE HYDRAULIC FRACTURE

RESEARCH AND ADVANCED TECHNOLOGY PROJECT

QUARTERLY REPORT: NOVEMBER 1976 THROUGH JANUARY 1977

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Prepared by Sandia Laboratories, Albuquerque, New Mexico 87115
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NATURAL GAS MASSIVE HYDRAULIC FRACTURE
RESEARCH AND ADVANCED TECHNOLOGY PROJECT

Quarterly Report: November 1976 through January 1977

Edited by: C. L. Schuster, Supervisor
Instrumentation Systems Division 5733
Sandia Laboratories
Albuquerque, New Mexico 87115

MASTER

Abstract

A small, shallow hydraulic fracture experiment was conducted with AMOCO and USGS near Tulsa, Oklahoma. The purpose of the experiment was to allow the tiltmeters and potential systems the opportunity to calibrate their models and compare their results with the known results. AMOCO is going to determine the fracture geometry by drilling into the suspected fracture location.

Design has been completed on the downhole seismic wall clamp system and fabrication and procurement has been initiated. The fielding of this system is expected next quarter and should provide the capability to map profiles close to the wellbore being fractured.

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I. Summary

This is the second quarterly report of the second reporting year for the Sandia Laboratories Program titled, "Natural Gas Massive Hydraulic Fracture Research and Advanced Technology Project." The program is funded by the Division of Oil, Gas and Shale Technology of ERDA. This report summarizes the activities from November 1, 1976 through January 31, 1977.

The only field experiment conducted during this period was a mini-frac near Tulsa, Oklahoma. This was a joint AMOCO/ERDA experiment with AMOCO conducting the fracture and Sandia and the USGS participating in the fracture diagnostic instrumentation. The fracture depth was extremely shallow to facilitate both the tiltmeter measurements and the AMOCO follow-on drilling program. They are planning a program to drill several holes to intercept the fracture for obtaining the ground truth on its orientation and height.

The design of the downhole wall clamped seismic system has been completed. The electronic design induces the clamping and release command circuitry as well as the circuitry for multiplexing data outputs from the three-axis geophones. Both magnetic and gyro compass systems with downhole cameras are being procured for

obtaining the system orientation. This will allow operation in cased and uncased wells. Mechanically and electrically, the systems are being designed to operate on the standard single conductor wireline.

II. AMOCO Mini-Frac (L. J. Keck)

The AMOCO Production Company performed a small scale hydrofracture experiment in a shallow formation on their Williams Lease northeast of Tulsa, Oklahoma on November 4, 1976. The purpose of this experiment was to test three methods of hydrofracture mapping instrumentation.

The fracture well was drilled to a depth of 80 feet and was cased to 40 feet. The fracture formation consisted of shaly limestone. Approximately 5000 gallons of fluid was pumped which was calculated to produce a fracture length of 700 feet.

Three types of instrumentation were employed. 1) Sandia installed a circular array to measure variations in surface potentials, 2) the USGS installed an array of nine tiltmeters to detect earth displacement, and 3) AMOCO has a downhole TV camera during the fracture to observe the orientation of the fracture in the wall of the test hole.

For Sandia measurements, the casing of the test hole and the casing of an abandoned test hole approximately 1400 feet away were used as current probes. Current was injected into the earth through these probes to create

an electrical potential field at the surface.¹ Potential probes were placed in a circular array around the test hole on 15 degree spacings at 150 feet and 350 feet radii. This array is illustrated in Fig. 1. Changes in the potential field results as the conductive fracture fluid propagates through the fractured formation. Figures 2 through 7 indicate an asymmetrical fracture propagating primarily in the East-West direction with the major element of the fracture going East. The data used to make these comparisons is listed in Table 1. The data values are surface potentials in volts.

Data taken from the downhole TV camera and the tiltmeters tend to verify this assumption. AMOCO will drill exploratory holes in an attempt to intercept the predicted fractures. Data from these tests are not yet available.

¹L. J. Keck and R. W. Seavey, "Instrumentation System for Massive Hydraulic Fracture Mapping," SAND-77-0195, Printed April 1977.

Fig. 1

Layout for Surface Potential Instrumentation

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

TABLE 1

TULSA MHF EXPERIMENT

FRACTURE-NOVEMBER 3, 1975

TIME		0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°
8:20		1.0295	1.1074	1.2270	1.1498	1.3701	1.6032	1.8148	1.6839	1.4816	1.2597	1.1858	1.1385
8:22		1.0252	1.1020	1.2233	1.1462	1.3654	1.5972	1.8066	1.6789	1.4767	1.2562	1.1834	1.1352
8:24		1.0261	1.1021	1.2227	1.1461	1.3650	1.5971	1.8074	1.6783	1.4721	1.2551	1.1829	1.1349
8:26		1.0273	1.1040	1.2248	1.1481	1.3578	1.5902	1.8115	1.6823	1.4811	1.2584	1.1858	1.1372
8:28	Breakdown	1.0335	1.1120	1.2325	1.1556	1.3764	1.6107	1.8236	1.6930	1.4893	1.2662	1.1924	1.1443
8:30		.9907	1.0642	1.1781	1.1035	1.3113	1.5299	1.7299	1.6089	1.4198	1.2392	1.1411	1.0942
8:32		.9911	1.0652	1.1795	1.1057	1.3129	1.5325	1.7341	1.6112	1.4166	1.2403	1.1422	1.0954
8:34		.9918	1.0651	1.1735	1.1063	1.3137	1.5345	1.7355	1.6123	1.4119	1.2109	1.1422	1.0952
8:35	Start pumping	.9915	1.0648	1.1754	1.1069	1.3153	1.5343	1.7343	1.5960	1.3965	1.1933	1.1365	1.0928
8:38		.9836	1.0521	1.1529	1.0903	1.2906	1.5047	1.7002	1.5837	1.4016	1.1940	1.1276	1.0807
8:40		.9803	1.0540	1.1526	1.0999	1.2888	1.5007	1.6956	1.5793	1.3993	1.1929	1.1272	1.0810
8:42	(2 BBL/MIN)	.9830	1.0549	1.1531	1.0914	1.2894	1.5005	1.6945	1.5802	1.4009	1.1944	1.1297	1.0822
8:44		.9885	1.0587	1.1586	1.0943	1.2924	1.5031	1.6935	1.5818	1.4018	1.1973	1.1332	1.0853
8:46	Stop pumping	.9941	1.0648	1.1730	1.0975	1.2934	1.4963	1.6912	1.5746	1.4019	1.1966	1.1358	1.0854
8:48		1.0004	1.0695	1.1757	1.0992	1.2863	1.4826	1.6782	1.5591	1.3953	1.1980	1.1371	1.0918
8:50		1.0036	1.0707	1.1812	1.1053	1.3041	1.5155	1.7050	1.5940	1.4144	1.2071	1.1419	1.0947
8:52		1.0069	1.0732	1.1814	1.1064	1.3043	1.5159	1.7026	1.5937	1.4102	1.2071	1.1423	1.0943
8:54		1.0012	1.0723	1.1818	1.1067	1.3056	1.5184	1.7126	1.5973	1.4103	1.2077	1.1419	1.0947
8:56		.9988	1.0714	1.1800	1.1032	1.2932	1.4941	1.6755	1.5723	1.3994	1.2015	1.1386	1.0925
8:58		.9997	1.0716	1.1805	1.1035	1.3040	1.5155	1.7098	1.5956	1.4084	1.2062	1.1411	1.0935
9:00		1.0042	1.0786	1.1876	1.1123	1.3110	1.5242	1.7115	1.6031	1.4155	1.2120	1.1466	1.0982
9:02		.9977	1.0696	1.1798	1.1049	1.3032	1.5156	1.7032	1.5949	1.4115	1.2056	1.1401	1.0913
9:04		.9977	1.0705	1.1792	1.1053	1.3032	1.5148	1.7063	1.5945	1.4112	1.2054	1.1397	1.0910
9:06		.9977	1.0714	1.1791	1.1051	1.3031	1.5151	1.7081	1.5936	1.4117	1.2054	1.1397	1.0916
9:08	Start pumping	.9980	1.0704	1.1797	1.1051	1.3037	1.5168	1.7062	1.5932	1.4112	1.2053	1.1397	1.0914
9:10		.9987	1.0701	1.1794	1.1059	1.3024	1.5148	1.7014	1.5926	1.4104	1.2054	1.1400	1.0912
9:12		1.0042	1.0776	1.1833	1.1089	1.3037	1.5137	1.7022	1.5917	1.4103	1.2071	1.1427	1.0939
9:14		1.0089	1.0813	1.1875	1.1125	1.3073	1.5173	1.7082	1.5955	1.4107	1.2090	1.1448	1.0958
9:16		1.0150	1.0853	1.1902	1.1145	1.3063	1.5123	1.6974	1.5889	1.4074	1.2085	1.1443	1.0962
9:22		1.0259	1.0967	1.2008	1.1243	1.3127	1.5148	1.6938	1.5893	1.4103	1.2120	1.1491	1.1004
9:24		1.0247	1.1026	1.2053	1.1291	1.3171	1.5193	1.7000	1.5959	1.4176	1.2156	1.1525	1.1033
9:26		1.0261	1.1080	1.1984	1.1242	1.3109	1.5112	1.6891	1.5842	1.4079	1.2098	1.1463	1.0972
9:28	(2 BBL/MIN)	1.0256	1.1090	1.2017	1.1252	1.3100	1.5100	1.6864	1.5825	1.4052	1.2083	1.1458	1.0963
9:30		1.0295	1.1021	1.2025	1.1266	1.3115	1.5098	1.6887	1.5838	1.4089	1.2084	1.1465	1.0968
9:32		1.0305	1.1015	1.2042	1.1269	1.3123	1.5114	1.6915	1.5822	1.4065	1.2076	1.1457	1.0963
9:34		1.0374	1.1099	1.2117	1.1344	1.3206	1.5183	1.6979	1.5910	1.4147	1.2145	1.1521	1.1025
9:36		1.0323	1.1048	1.2060	1.1291	1.3126	1.5076	1.6832	1.5804	1.4015	1.2065	1.1452	1.0953
9:38		1.0338	1.1064	1.2062	1.1286	1.3131	1.5095	1.6849	1.5802	1.4052	1.2065	1.1445	1.0945
9:40		1.0277	1.0994	1.1976	1.1205	1.3036	1.4974	1.6759	1.5730	1.3954	1.1958	1.1355	1.0855
9:42		1.0351	1.1080	1.2064	1.1288	1.3135	1.5078	1.6841	1.5780	1.4037	1.2054	1.1437	1.0948
9:44	Stop pumping	1.0369	1.1082	1.2062	1.1303	1.3127	1.5073	1.6836	1.5771	1.4032	1.2052	1.1437	1.0936
9:46		1.0247	1.0968	1.1967	1.1150	1.2802	1.4595	1.6131	1.5292	1.3769	1.1895	1.1319	1.0849
9:48		1.0167	1.0893	1.1927	1.1172	1.3099	1.5127	1.6905	1.5864	1.4055	1.2020	1.1375	1.0879
9:50		1.0228	1.0949	1.1956	1.1209	1.3104	1.5106	1.6922	1.5833	1.4056	1.2050	1.1422	1.0922
9:52		1.0240	1.0975	1.1945	1.1218	1.3099	1.5078	1.6927	1.5806	1.4033	1.2050	1.1424	1.0928
9:54		1.0267	1.0994	1.2004	1.1227	1.3102	1.5097	1.6939	1.5802	1.4021	1.2038	1.1421	1.0916
9:56		1.0335	1.1065	1.2067	1.1292	1.3185	1.5165	1.6942	1.5911	1.4089	1.2118	1.1487	1.0980
9:58		1.0272	1.0978	1.1999	1.1215	1.3098	1.5085	1.6830	1.5810	1.4049	1.2047	1.1421	1.0915
10:00		1.0278	1.0998	1.2007	1.1223	1.3101	1.5101	1.6931	1.5817	1.4056	1.2052	1.1421	1.0912

TABLE 1 (con't)

TULSA MHF EXPERIMENT												
FRACTURE-NOVEMBER 3, 1976												
TIME	180°	195°	210°	225°	240°	255°	270°	285°	300°	315°	330°	345°
8:20	.9743	1.1291	1.1444	1.0546	1.1033	1.1386	1.1320	1.0944	1.0692	.9788	.9494	.9649
8:22	.9709	1.1259	1.1417	1.0516	1.1010	1.1350	1.1273	1.0903	1.0654	.9750	.9466	.9623
8:24	.9692	1.1257	1.1408	1.0509	1.1005	1.1353	1.1259	1.0900	1.0657	.9747	.9453	.9615
8:26	.9703	1.1278	1.1432	1.0520	1.1018	1.1352	1.1132	1.0899	1.0661	.9758	.9484	.9629
8:28	.9753	1.1349	1.1502	1.0579	1.1077	1.1419	1.1201	1.0972	1.0726	.9818	.9539	.9697
8:30	.9353	1.0868	1.1002	1.0116	1.0604	1.0921	1.0717	1.0498	1.0275	.9423	.9143	.9300
8:32	.9325	1.0878	1.1011	1.0128	1.0610	1.0933	1.0729	1.0510	1.0284	.9429	.9157	.9294
8:34	.9341	1.0878	1.1012	1.0126	1.0618	1.0937	1.0714	1.0521	1.0285	.9429	.9154	.9306
8:36	.9322	1.0884	1.1028	1.0137	1.0631	1.0958	1.0745	1.0526	1.0302	.9441	.9169	.9308
8:38	.9243	1.0748	1.0859	.9984	1.0480	1.0797	1.0582	1.0376	1.0154	.9322	.9054	.9196
8:40	.9233	1.0753	1.0374	.9990	1.0477	1.0793	1.0589	1.0384	1.0166	.9335	.9070	.9214
8:42	.9234	1.0772	1.0391	.9998	1.0500	1.0811	1.0607	1.0402	1.0192	.9357	.9081	.9229
8:44	.9271	1.0816	1.0933	1.0035	1.0542	1.0860	1.0655	1.0457	1.0234	.9408	.9132	.9277
8:46	.9307	1.0862	1.0981	1.0082	1.0584	1.0911	1.0729	1.0509	1.0294	.9474	.9192	.9332
8:48	.9328	1.0899	1.1021	1.0114	1.0584	1.0957	1.0764	1.0556	1.0352	.9521	.9247	.9389
8:50	.9355	1.0910	1.1031	1.0117	1.0620	1.0967	1.0761	1.0574	1.0350	.9523	.9247	.9396
8:52	.9336	1.0905	1.1032	1.0111	1.0622	1.0966	1.0761	1.0567	1.0358	.9524	.9248	.9391
8:54	.9336	1.0906	1.1028	1.0110	1.0624	1.0968	1.0761	1.0563	1.0358	.9517	.9245	.9387
8:56	.9324	1.0897	1.1024	1.0104	1.0614	1.0964	1.0759	1.0566	1.0344	.9513	.9245	.9391
8:58	.9336	1.0897	1.1016	1.0095	1.0630	1.0952	1.0752	1.0549	1.0339	.9537	.9233	.9383
9:00	.9377	1.0952	1.1070	1.0146	1.0672	1.1009	1.0805	1.0607	1.0396	.9554	.9286	.9430
9:02	.9318	1.0890	1.1007	1.0084	1.0612	1.0943	1.0742	1.0545	1.0328	.9499	.9223	.9370
9:04	.9316	1.0880	1.1004	1.0076	1.0573	1.0939	1.0734	1.0540	1.0323	.9495	.9221	.9370
9:06	.9306	1.0881	1.1001	1.0070	1.0612	1.0948	1.0745	1.0537	1.0319	.9499	.9223	.9369
9:08	.9305	1.0877	1.0997	1.0069	1.0597	1.0936	1.0746	1.0532	1.0320	.9500	.9224	.9367
9:10	.9301	1.0885	1.1001	1.0068	1.0607	1.0936	1.0735	1.0531	1.0334	.9513	.9230	.9377
9:12	.9349	1.0918	1.1031	1.0093	1.0652	1.0977	1.0776	1.0587	1.0388	.9576	.9288	.9435
9:14	.9360	1.0943	1.1056	1.0105	1.0668	1.1001	1.0798	1.0621	1.0413	.9606	.9333	.9482
9:16	.9433	1.0957	1.1067	1.0121	1.0689	1.1019	1.0820	1.0642	1.0447	.9635	.9371	.9505
9:22	.9578	1.1015	1.1120	1.0164	1.0742	1.1078	1.0903	1.0721	1.0535	.9734	.9433	.9630
9:24	.9585	1.1044	1.1147	1.0192	1.0764	1.1104	1.0912	1.0760	1.0567	.9775	.9469	.9652
9:26	.9493	1.0989	1.1085	1.0140	1.0715	1.1052	1.0858	1.0705	1.0523	.9734	.9472	.9623
9:28	.9475	1.0984	1.1079	1.0133	1.0710	1.1051	1.0863	1.0717	1.0522	.9748	.9492	.9648
9:30	.9457	1.0986	1.1084	1.0136	1.0719	1.1056	1.0860	1.0715	1.0537	.9765	.9507	.9667
9:32	.9448	1.0976	1.1079	1.0134	1.0718	1.1051	1.0866	1.0714	1.0543	.9772	.9510	.9682
9:34	.9556	1.1043	1.1138	1.0189	1.0779	1.1115	1.0926	1.0790	1.0611	.9835	.9579	.9750
9:36	.9445	1.0973	1.1072	1.0129	1.0716	1.1049	1.0867	1.0731	1.0556	.9792	.9542	.9698
9:38	.9430	1.0955	1.1067	1.0126	1.0711	1.1049	1.0861	1.0730	1.0561	.9792	.9547	.9715
9:40	.9320	1.0865	1.0958	1.0039	1.0626	1.0965	1.0814	1.0643	1.0482	.9741	.9469	.9645
9:42	.9433	1.0954	1.1054	1.0119	1.0732	1.1047	1.0864	1.0737	1.0563	.9814	.9563	.9727
9:44	.9440	1.0959	1.1056	1.0123	1.0698	1.1048	1.0859	1.0738	1.0574	.9819	.9572	.9745
9:46	.9366	1.0882	1.0999	1.0071	1.0645	1.0979	1.0795	1.0653	1.0477	.9764	.9464	.9626
9:48	.9342	1.0881	1.0991	1.0065	1.0628	1.0957	1.0761	1.0599	1.0418	.9651	.9383	.9537
9:50	.9416	1.0930	1.1038	1.0112	1.0676	1.1039	1.0837	1.0662	1.0487	.9714	.9462	.9602
9:52	.9423	1.0943	1.1042	1.0116	1.0678	1.1020	1.0827	1.0683	1.0511	.9745	.9481	.9640
9:54	.9416	1.0940	1.1042	1.0120	1.0685	1.1017	1.0829	1.0675	1.0515	.9755	.9484	.9644
9:56	.9481	1.0995	1.1103	1.0171	1.0742	1.1075	1.0881	1.0753	1.0576	.9811	.9562	.9705
9:58	.9410	1.0904	1.1033	1.0117	1.0674	1.1036	1.0817	1.0672	1.0508	.9751	.9483	.9650
10:00	.9420	1.0927	1.1031	1.0126	1.0674	1.1001	1.0816	1.0676	1.0506	.9749	.9493	.9648

III. Downhole Seismic System (R. W. Seavey)

Examination of arrival times and polarization of seismic signals generated by hydraulic fractures may be used to map the size and orientation of those fractures.² By employing a triaxial geophone package which is clamped to the borehole near the start of the fracture, the direction and distance to the seismic events created by the fracturing can be determined. Examination of a sufficient quantity of these seismic events may be used to determine the profile and orientation of the fracture near the wellbore.

The signals from two horizontal geophones may be used to calculate the azimuth direction of the event. A vertical geophone in conjunction with the horizontal geophones may be used to determine the angle of inclination to the source. Measurement of the difference in arrival times of the compressional wave (p-wave) and the shear wave (s-wave) may be used to calculate the distance to the seismic event if the velocities of these waves are known. The addition of a package orientation device permits mapping of the fractures with respect to some geophysical reference.

² Los Alamos Scientific Laboratories Progress Report - LA-6525PR, "LASL Hot Dry Rock Geothermal Project, July 1, 1975 - June 30, 1976," compiled by A. G. Blair, J. W. Tester, and J. J. Mortensen.

A Borehole Seismic Locator (BSL) has been designed and is now in the process of fabrication. A triaxial geophone system has been incorporated with a mechanism to clamp the BSL to the wall of the borehole. The BSL will be 3-5/8 inches in diameter and up to 16 feet long, capable of being locked to boreholes from 4-1/2 inches to 15 inches in diameter.

Figure 8 shows component arrangement of the BSL. Power is supplied to the unit by means of a single conductor logging cable. Signals are sent to the surface over the same cable. The electronics package provides amplification for the geophone signal and controls for the clamping mechanism. The motor, arm drive, and clamping arm is the means for clamping the BSL to the wall. This unit is a portion of Geo Space Corporation Wall Lock Geophone system. The triaxial geophones are two horizontal and one vertical L-25A geophones produced by Mark Products. Orientation of the BSL will be determined by using a photographic compass unit in open holes or a gyro unit in casual holes. The compass unit contains a timed camera and a magnetic angle unit. Periodic photographs will be taken giving magnetic bearings and angle of inclination of the BSL. The gyro unit utilizes the same photographic unit in conjunction with a directional gyro and a gyro angle unit. The photographs will

Fig. 8

Borehole Seismic Locator

be developed after the BSL has been removed from the borehole. Both orientation devices have been purchased from Humphrey, Inc. Figure 9 is a block diagram of the BSL electronics.

The signals from the triaxial geophone array are amplified in Sandia Laboratories designed amplifier and modulate voltage controlled oscillation (VCO's). The VCO signals are multiplexed and transmitted to the surface through a line driven and a single wire line. At the surface, these signals will be recorded on a magnetic tape recorder. Power to the system will be supplied from the surface over the same single wire line.

The clamping mechanism consists of a D.C. motor driven arm controlled by tone decoders and latching relays. Power to the motor is also supplied from the surface. A fourth VCO is used to monitor the clamping arm position and is multiplexed with the other VCO's.

The Borehole Seismic Locator is expected to be complete by April 1, 1977. At that time, evaluation tests will be performed in an experimental hole to be drilled at Kirtland Air Force Base, just west of Coyote Canyon. This site is located on a knoll of limestone surrounded by outcropping of the same limestone bed. The locator will be lowered into the test hole and

Fig. 9

Borehole Seismic Locator Electronics

recordings will be made at various depths while explosive charges are detonated in a number of the limestone out croppings.

These tests will provide information for refinement of package handling procedures and analysis of the recorded data will be used to evaluate signal procession techniques, accuracy limitations, signal strengths, and computer programs.

Tests are also expected to be conducted with the locator at the Nevada Test Site during hydraulic fracturing experiments. Recordings made during these tests will provide fracture seismic signal characterization and provide further information as to the accuracy of the system since mineback is planned in order to determine the size and extent of the fracture.

IV. Simulation Experiments (G. B. Griswold)

An experimental hydraulic fracturing program with both containment and natural gas stimulation objectives is being conducted in G tunnel in Rainier Mesa at the Nevada Test Site. A fracturing test which would primarily investigate the behavior of a fracture at a geological formation interface has been proposed by FY'77.

Adjacent to existing tunnel activities in an ash fall tuff and welded tuff interface. These formations have significantly contrasting properties as shown in Table 2 and provide a meaningful test location. While further details need to be finalized, the present schedule calls for exploratory core drilling from the tunnel (January-February 1977), drilling the fracture well from the mesa to tunnel level (end of February), design culminating the two-fracture field test (April-May), and with mineback initially being conducted in the last quarter of FY'77. This well will be officially designated UE12G10.6 or Well 6 for this Program.

A proppant distribution test was conducted in Well 5 in July 1976 and coring and mineback activities were approaching this site in December. Large open fractures (up to 12") have been discovered upon mineback. The source of these (natural or nuclear-caused) is not

Table II

Tuff Formation Properties, G Tunnel, Nevada Test Site

	<u>Ash-Fall Tuff</u>	<u>Welded Tuff</u>
Bulk Density (g/cm ³)	1.77	2.19
Grain Density (g/cm ³)	2.42	2.61
Porosity* (%)	44.6	24.1
Modulus of Elasticity (x 10 ⁶ psi)	0.236	2.41
Poisson's Ratio	0.312	0.238
Bulk Modulus* (x 10 ⁶ psi)	0.21	2.1
Shear Modulus* (x 10 ⁶ psi)	0.11	1.1
Permeability** (millidarcy)	2.29	0.011

*Calculated from other properties

**Helium permeability on 4.75 cm diameter by 5.18 cm long specimens, as received, zero confining pressure and 300 psi driving pressure. (Our experience indicates that under small confining pressures, permeability values may be one or two orders of magnitude smaller.)

known and they were not intersected by two pre-test
exploratory holes into this test region. Careful examina-
tion of this region will be made.

V. Future Experiments

Table III lists the presently planned joint industry/ERDA experiments and their locations. These fracture tests will utilize the surface electrical potential system and should verify some of the unknown parameters necessary to complete the system performance specifications.

Table III

Future Hydraulic Fracture Experiments

Gas Producing Enterprises	Vernal, Utah
Columbia Gas	Lincoln Co., W. Va.
AMOCO	Wattenberg, Colorado
CONOCO	Casper, Wyoming
Mobil	Rio Blanco, Colorado
Pacific Transmission Supply	Vernal, Utah

The downhole seismic system will be tested in Albuquerque in a shallow well for design verification. Preliminary plans then are to do some small fractures at NTS to investigate seismic signal generation and location. Following these experiments, the system should be ready for a full-scale test in a massive fracture well. AMOCO has expressed interest in utilizing the seismic system for some breakdown tests in their wells in the Wattenberg field.

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