STIMULATION AND BACKFLOW OF WATER INPUT WELLS USING NITROGEN TECHNIQUES

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INTRODUCTION

A stimulation treatment of water input wells in the massive San Andres limestone has shown the benefits that can be expected with the inclusion of nitrogen in the treatment followed by the use of nitrogen for displacement to the formation and the subsequent backflow.

The San Andres is interspersed with water zones and the multiphase system helps prevent the fracturing of the formation due to gas compressibility and carefully controlled injection rates.

The inclusion of a gas phase in stimulation treatments has been practiced for many years in production wells, but it has been only recently accepted in the treatment of water input wells in the Southwest. Wells treated cover the six-county area of Hockley, Terry, Cochran, Yoakum, Gaines and Scurry Counties.

Two treatment techniques developed have shown that with a properly engineered treatment an increase of water input and effective cleanout of solids can be expected.

WELL CONDITIONS

Wells in the San Andres formation usually have 100-150 ft exposed to injection. The majority of wells are open-hole completions below the casing. Internally coated tubing is set on a packer up in the cased hole. In perforated completions the same general conditions apply.

Fracture gradients in the average 5000-ft wells normally vary from 0.6-0.7 psi per foot of depth.

As input water volume decreases and wellhead pressures increase, two unfavorable conditions exist: (1) well efficiency decreases with a resultant higher cost per barrel of oil produced and (2) the possibility of fracturing the formation is present which could divert water to an undesirable or no-pay zone. It is absolutely essential to hold wellhead pressures below the frac gradient. In a high percentage of wells treated, the maximum wellhead pressure had been attained prior to treatment and water input was decreasing.

Low permeability and plugging due to iron sulfides, carbonates or other insoluble precipitates cause the two conditions described above. The permeability can be improved with the proper selection of acid. The prime requisite of a successful treatment is to remove soluble and insoluble precipitates from the formation to the wellbore and on out to the surface.

TECHNIQUES AND TREATMENT

A workover rig is moved in to remove the packer and coated tubing. A measuring line is then run to check for fill. In many cases, if fill is present, it may be removed with a wireline bailer or reverse circulation unit. Then a work string and packer are run and the packer is set in the casing above the zone to be treated. A test tank is set and hooked up to store the recovered fluids. The acid service company and the nitrogen service company are called to tie in to the wellhead for the stimulation treatment. See Fig. 1, a nitrogen truck on location.

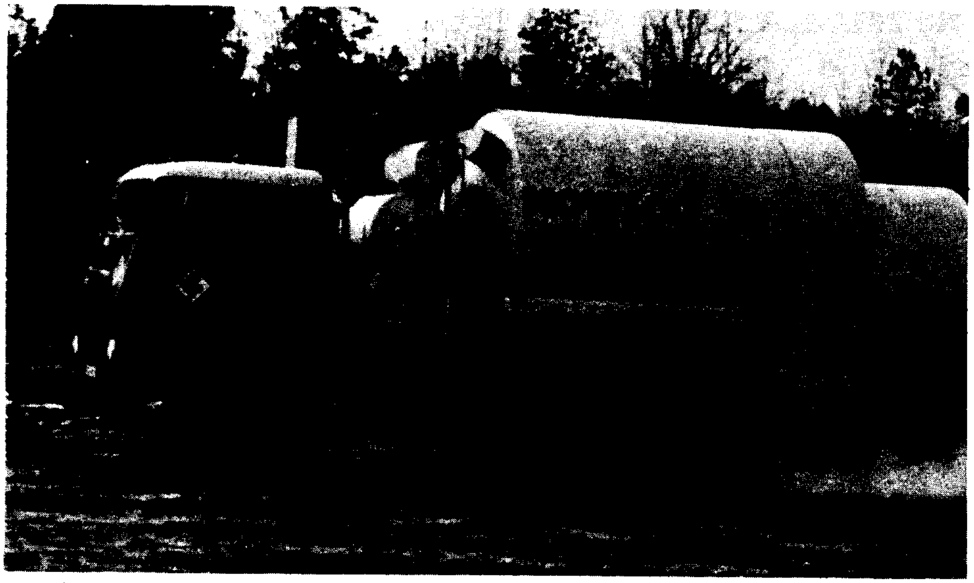

FIG. 1—A NITROGEN TRUCK ON LOCATION

The treatment consists of the following:

1. A spearhead of 50,000-60,000 SCF nitrogen to create a new temporary bottomhole pressure and to determine injection rate from data recorded. This also is a source of high pressure energy for backflow.
2. Fifteen percent hydrochloric nonemulsifying acid, using 40-60 gal. of acid per foot of exposed formation; acid to contain iron control additives and inhibited to the proper time and temperature.
3. All acid to be commingled with engineered volumes of nitrogen for ease of injection and effective backflow.[1]
4. A temporary plug of 100-150 lb of benzoic acid flakes or benzoic acid flakes and rock salt mixed in 250 gal. of gelled acid at the proper stage or stages for diverting the treatment to alternate or secondary zones. If profile analysis shows input water all going to a lower zone, then a bridge plug could properly be considered to divert to the upper zones.
5. Displacement with nitrogen to the formation to clear tubing and allow rapid backflow.
6. Backflow well at high rate to storage tank.

During the spearhead of nitrogen, acid treatment, and final nitrogen displacement, the wellhead treating pressure is monitored constantly to observe pressure breakdowns and adjust rates to remain under frac gradients.

To determine the maximum wellhead pressure with the full column of gas during the spearhead and stay below predetermined fracture pressure of the formation, Table 1 is used.[2] From this table, it may be seen that for a 5000-ft well, with a fracture pressure of 3500 psi, the surface pressure would be approximately 2940 psi.

Depth Feet \ P_W psia	500	1000	1500	2000	2500	3000	3500	4000
500	509	1017	1527	2036	2547	3059	3572	4060
1000	517	1035	1553	2073	2594	3117	3644	4121
1500	526	1052	1580	2109	2641	3175	3715	4180
2000	534	1070	1606	2145	2687	3233	3785	4240
2500	543	1087	1633	2181	2733	3291	3855	4299
3000	552	1104	1659	2217	2780	3348	3925	4358
3500	560	1122	1685	2253	2825	3405	3994	4417
4000	569	1139	1712	2289	2871	3462	4049	4475
4500	577	1156	1738	2324	2917	3518	4102	4533
5000	586	1174	1764	2360	2962	3574	4156	4591
5500	595	1191	1791	2395	3008	3630	4209	4649
6000	603	1208	1817	2431	3053	3686	4263	4706
6500	612	1226	1843	2466	3098	3742	4316	4763
7000	621	1243	1869	2501	3143	3797	4368	4820
7500	629	1260	1895	2537	3187	3852	4421	4877
8000	638	1278	1921	2572	3232	3906	4474	4933
8500	647	1295	1947	2607	3276	3961	4526	4989
9000	655	1312	1974	2642	3321	4008	4578	5045
9500	664	1329	2000	2677	3365	4055	4630	5101
10000	673	1347	2026	2712	3409	4101	4681	5157
10500	681	1364	2051	2746	3453	4148	4733	5213
11000	690	1381	2077	2781	3497	4194	4784	5268
11500	699	1399	2103	2816	3541	4240	4836	5323
12000	707	1416	2129	2851	3585	4286	4887	5378
12500	716	1433	2155	2885	3629	4332	4938	5433
13000	725	1451	2181	2920	3672	4378	4989	5488
13500	734	1468	2207	2954	3716	4424	5039	5542
14000	742	1485	2232	2989	3759	4470	5090	5597
14500	751	1502	2258	3023	3802	4515	5141	5651
15000	760	1520	2284	3057	3845	4561	5191	5705
15500	769	1537	2310	3092	3888	4606	5241	5760
16000	777	1554	2335	3126	3931	4651	5291	5813
16500	786	1572	2361	3160	3974	4697	5341	5867
17000	795	1589	2387	3194	4013	4742	5391	5921

* Temp. Grad. was assumed as, T = 74 + 1.6 (L-100) °F.

TABLE 1—PRESSURE AT DEPTH DUE TO A COLUMN OF NITROGEN HAVING A WELL-HEAD PRESSURE, PW (PSIA)*

This pressure relationship may also be calculated from the general gas equation:

$$P_B = P_S e^{\left(\frac{LG}{ZT\,53.34}\right)}$$

or:

$$P_B = P_S e^{\left(\frac{LG.01875}{ZT}\right)}$$

Where:

P_B = Pressure at bottom of gas column, psi absolute

PS = Pressure at wellhead, psi absolute

L = Length of gas column, ft

G = Specific gravity of gas; air = 1.0

Z = Average compressibility factor of gas

T = Average temperature of gas in tubing, absolute temp. (F° + 460°)

e = Naperian logarithm base = 2.71828

Acid pressure gradients are changed considerably with the inclusion of a gas phase. To determine the maximum treating pressure at the surface with 500 SCF/bbl, refer to Fig. 2. If the desired maximum bottomhole treating pressure is 3500 psi, refer to this figure on the abscissa and read down to the acid line, then read across to the ordinate of a new reference depth (19,000). Subtract the actual well depth from the reference depth and assuming a 5000-ft well the new reference depth is 14,000 ft. Read back to the acid line and read up to a maximum static wellhead pressure of 1925 psi with the conditions as shown in the inset. To this, a value for friction must be added, and can be approximated from Fig. 3. After the well is opened to atmosphere the bottomhole flowing pressure may be calculated from the same illustration.

With the use of a multiphase treating system a more even distribution of treating fluid over the entire zone can be expected.[1]

The volume factor of acid in the above conditions has increased 0.6 bbl per barrel for extended areal coverage. Fluid pump rates have varied from ¼ BPM to 3 BPM. At the

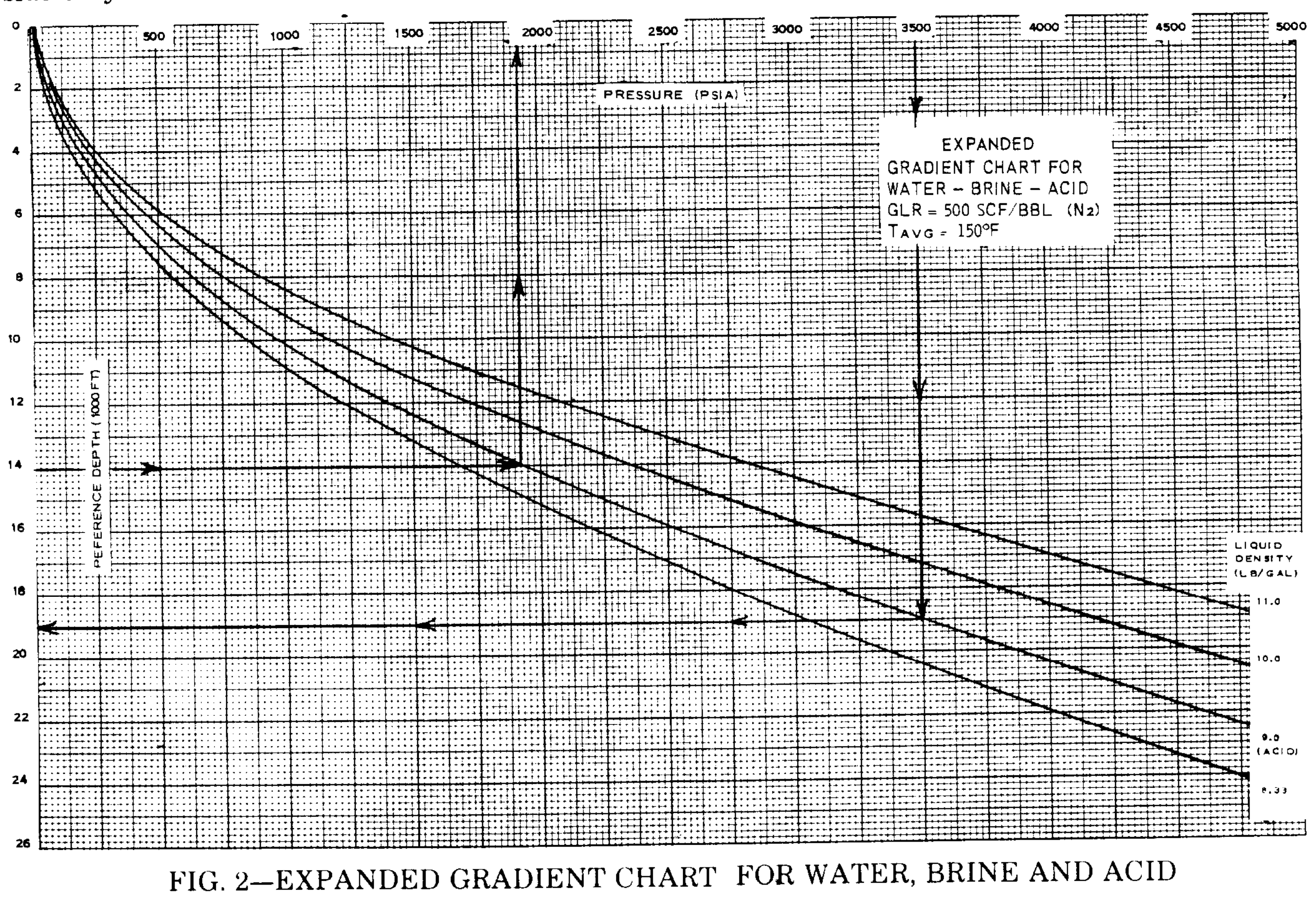

FIG. 2—EXPANDED GRADIENT CHART FOR WATER, BRINE AND ACID

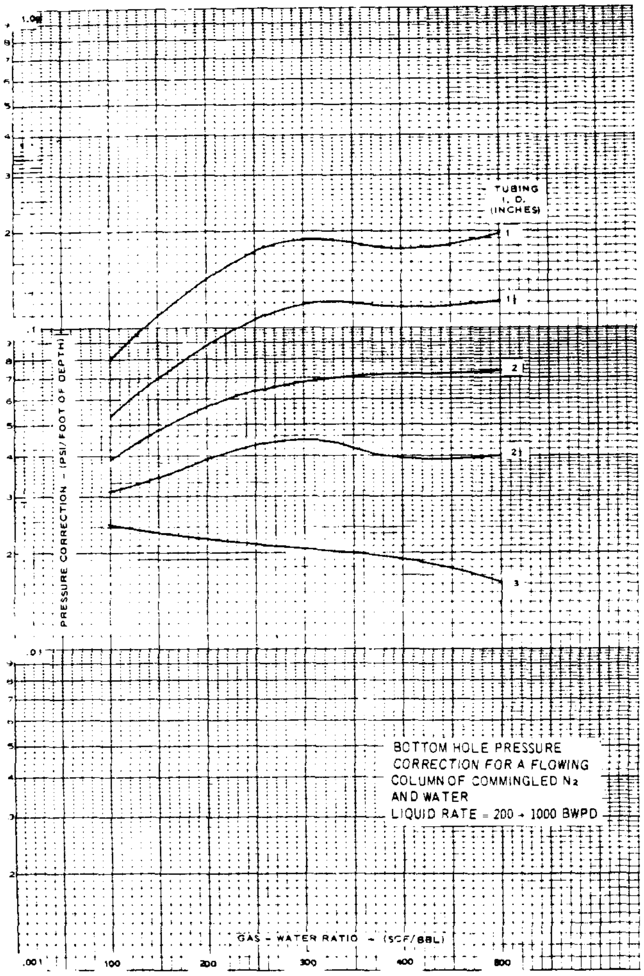

FIG. 3—BOTTOMHOLE PRESSURE CORRECTION FOR A FLOWING COLUMN OF COMMINGLED N_2 AND WATER

selected stage, the diverting material is added to a slug of gelled acid.

After treating fluid is pumped, commence the displacement to the formation with nitrogen using Table 1 to again determine maximum wellhead pressure to prevent exceeding frac gradient.[2]

After displacement is completed, rig-down stimulation company equipment and commence backflow to remove acid water and precipitates as seen in Fig. 4.

An alternate method for removing fill and for backflow of the stimulation treatment involves using a ¾-in. continuous coiled tubing unit. The steel tubing is coiled on a steel reel in lengths up to 14,000 ft, and is injected into and from the well by the use of a tubing injector that is rigged on top of the wellhead and is capable of injecting tubing into the well up to 5000 psi, Fig. 5. This injector is an endless-chain, traction-type tubing injector, which is driven by a hydraulic motor. The tubing is gripped on each side by a series of contoured metal blocks in the endless chain mechanism. The injector is capable of exerting an upward or downward force of 8000 lb.

Adjustable grooved sheaves guide and straighten the tubing as it feeds into the injector. An automatic electro-mechanical counter records the amount of tubing run in the hole. Lubricators and blow-out preventers are all hydraulically operated.

The coiled tubing is injected into the well down the work string. After reaching the selected depth, fluid or nitrogen is pumped through the coiled tubing at the hub of the reel. Circulation is up the work string to the holding tanks. With the ability to reciprocate, washing or jetting the fill has presented no problems. Special washing tools can be installed at the bottom of the coiled tubing to create a vortex that effectively washes an open-hole section. Treatment may follow down the work string and then be jetted back with nitrogen. The placement of acid in the proper zone can also be accomplished by the use of the coiled tubing as described by Taylor and Plummer.[5] The coiled tubing can be used as a work string and at the same time be used as a single-point gas lift system with nitrogen. A single-point gas lift system guarantees 100% returns of acid water and soluble or insoluble precipitates. By jetting back immediately, returning treatment and solids up the work string to the storage tank, the risk of formation damage is minimized.[6]

A typical program in Hockley County produced the results shown in Table 2. These results are fairly representative of the wells treated.

CONCLUSION

Treatments using nitrogen techniques have proven to be effective in the backflow of water input wells. Total cost of these stimulations may be as much as $6000 each, depending upon size of treatment and total services required. With over 140 wells treated in this manner in the Southwest, the success ratio has reached the level most customers consider as economical and successful from several viewpoints. Down-time is held to a minimum, and returns

FIG. 4—BACKFLOW WITH NITROGEN

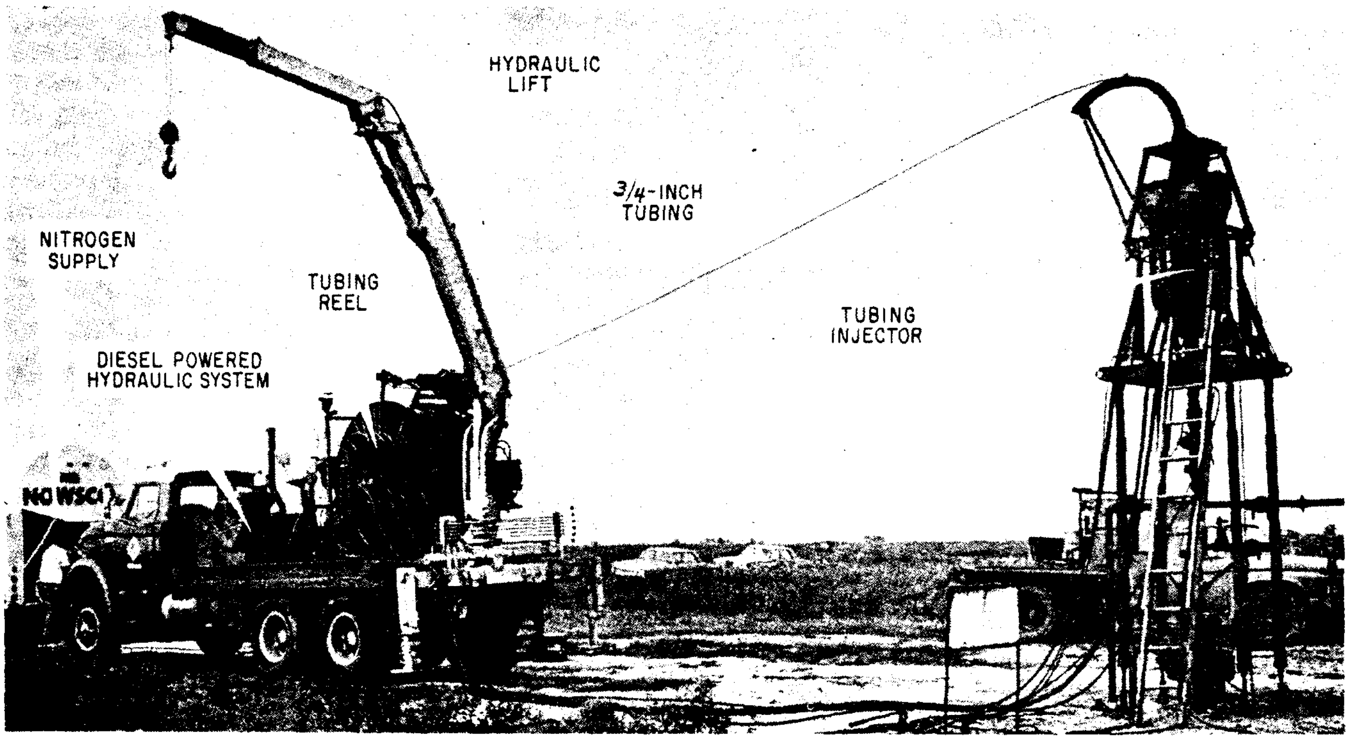

FIG. 5—CONTINUOUS COILED TUBING UNIT

to the surface prove the theory of cleaning up the well. The successful results are probably the combination of several factors including the solubility of the acid, cleaning out of fill, the diverting of treatment to alternate zones, and the very effective backflow and removal of solids and spend acid by the inclusion of nitrogen in the treatment.

TABLE 2

BEFORE TREATMENT		AFTER TREATMENT	
VOLUME BWPD	PRESSURE PSI	VOLUME BWPD	PRESSURE PSI
1660	1400	1844	1375
1500	1300	1695	1300
450	1400	635	1175
725	1250	835	1250
264	1150	375	1175
950	1400	1435	1300
1000	1350	1269	1325
1550	1300	1579	700
1069	1350	1383	1350
740	1300	1164	1275
450	960	520	970
325	1080	390	1080
370	1250	480	1250
265	1320	190	1300
185	1150	210	1150
260	1260	320	1260
250	1130	300	1130
75	1020	310	1070
290	1250	390	1260
110	1450	270	1450
12,488		15,594	

Resulting in an average increase of 155 BWPD/Well.

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