RECENT DEVELOPMENTS IN GAS FRAC

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INTRODUCTION

Use of liquefied gases as fracture fluids[1] has been a commercially available service for more than a year and both results and experience have helped dictate new developments and define candidate reservoirs. Designed originally for gas well stimulation, the new service uses a fluid made up of liquefied CO_2, LPG and methyl alcohol. The liquefied gases are mixed in such a proportion that they remain a liquid and behave as a liquid as long as they are under adequate pressure and below the critical temperature of the mixture. When they are heated above their critical temperature in the reservoir and pressure released, the liquid reverts to a gas. This results in extremely rapid clean-up and minimizes problems of water sensitivity and liquid retention damage.

In practice, the liquefied gases are mixed in varying proportions depending on reservoir temperature. For each well, the proportion is designed to provide a mixture that will have a critical temperature about 15% below the reservoir temperature. Since the mixture is not an effective frac fluid in itself, a gelling agent in methyl alcohol is added as a third component to provide the desired properties of viscosity, low leak-off or fluid loss control, low friction pressures, and good prop-carrying ability. In a stimulation treatment, the liquefied gases are mixed in proper proportion on location and pumped to the wellhead. The gelled alcohol and prop are mixed using a special pressurized blender and pumped to the wellhead where they mix with the liquefied gas mixture to produce a uniform prop-laden frac fluid. Not only is it necessary to design the liquefied gas mixture to have the proper critical temperature for each well, but it is also necessary to design the methyl alcohol gel to provide the desired frac fluid properties to the final fluid for each well. Properties of the final fluid are determined from conventional fracture design calculations. (Although addition of the gelled alcohol to the liquefied gases increases the critical temperature of the mixture, laboratory data indicate that this increase is more than offset by designing the liquefied gas mixture to have a critical temperature 15% below reservoir temperature. In low-temperature wells, design is based on vapor pressure of the liquefied gas mixture as compared to reservoir pressure.)

AREAS OF USE

During the past year, liquefied gas frac fluids (gas frac for simplicity) have been used extensively in South Texas, West Texas, Western Oklahoma and the Rocky Mountain region. While results (Table 1) have been excellent, some problems have been encountered which have led to new developments and to modifications of the service. Some of the problems encountered were:

1. Water sensitivity of gelling agent for alcohol
2. Handling problems
3. Return of fluid components as liquid following treatment
4. High initial cost
5. Unavailability of liquefied CO_2 in some areas
6. Lack of properly equipped pressurized transports for liquefied gases (field storage trailers)
7. Inadequate response of some reservoirs.

The gelling agent for alcohol used initially in gas frac treatments was water-sensitive in that contact with water in the formation could cause a precipitate which might restrict production. This problem is not severe in wells with bottom temperatures above 150°F. It has led to the practice of classifying wells with high water content or those which will mist free water during production as poor candidates or noncandidates for gas frac treatments.

TABLE 1—RESULTS OF GAS FRAC TREATMENTS

State & County	Formation	Depth (feet)	Volume (gallons)	Avg Rate (BPM)	Treating Pressure (psi)	Prop Size	Prop Pounds	Daily Production Before	Daily Production After
Texas Lipscomb	Morrow	8,980	19,500	12	5,300	20-40 12-20	6,500 1,000	850 MCF 37 BO	1200 MCF 86 BO
Okla. Woodward	Morrow	6,340	19,000	15	4,000	20-40	12,000	70 MCF	Abandoned
Okla. Harper	Morrow	7,195	21,000	15	3,400	20-40	13,000	1.85 MMCF (CAOF)	30.6 MMCF (CAOF)
Texas Ochiltree	Cleveland	7,000	34,000	18	3,600	20-40	17,000	140 MCF	170 MCF
Okla. Cimarron	Keys Sand	4,600	13,000	13	3,150	20-40	6,500	1 MMCF @ 390 psi	1.3 MMCF @ 390 psi
Texas Sutton	Canyon Sand	6,009	29,000	12.5	3,000	40-60 20-40	2,000 22,800	50 MCF (OF)	1.5 MMCF @ 600 psi
Texas Sutton	Canyon Sand	6,010	50,000	15.5	3,500	20-40	19,000	750 MCF (OF)	2 MMCF @ 280 psi
New Mexico Lea	Queens Sand	3,996	17,500	17	4,100	20-40	14,000	10 MCF (OF)	600 MCF @ 80 psi
Texas Sutton	Strawn	6,450	26,500	15	6,500	20-40	16,300	249 MCF @ 295 psi	1 MMCF @ 900 psi
Texas Edwards	Holleman Sand	6,230	17,500	19	3,600	20-40	15,000	125 MCF @ 70 psi	11.2 MMCF (CAOF)
Alberta	Viking A	2,900	13,300	16	1,800	20-40 10-20	10,000 20,000	100 MCF (OF)	640 MCFD @ 120 psi

The water sensitivity of the gelling agent also dictates another precaution. While it might be tempting to use cheaper grades of methyl alcohol to prepare the gel, these grades generally contain up to 20% or more water and can lead to serious problems. Not only could an improper gel result in a screenout, but also a serious plugging problem could occur even if the job were successfully completed. Therefore, only the best grade of alcohol should be used.

Another problem with the original gelling agent used was handling problems. The agent had a tendency to lump in storage and cause mixing problems. Furthermore, it has generally been necessary to mix the alcohol and gelling agent and allow it to stand overnight to achieve desired viscosity. To overcome these problems, a new polymer gelling agent has been developed. This agent disperses readily and provides proper viscosity in about 30 minutes. This rapid viscosity development permits gelling operations during hook-up for the treatment and reduces pre-job preparation considerably.

RETURN OF LIQUIDS

In some areas, liquid components have been returned to the wellbore following gas frac treatments. In most cases, it has been found that the returned liquid is the alcohol in water or liquid hydrocarbon. The behavior of the frac fluid in the reservoir as individual components could be accounted for by improper mixing of the liquefied gases and gelled alcohol at the surface. This would result in a nonhomogeneous fluid. It is more likely, however, that some reservoir fluids are also involved since the phenomenon appears to be limited to specific areas rather than an occasional occurrence throughout all the areas where the treatment has been used.

HIGH INITIAL COST

High initial cost of gas frac treatments in comparison with more conventional fracturing treatments is primarily due to more expensive fluid components and to the need for specialized equipment. Equipment costs have been considerably reduced recently. As in all new services, limited equipment is available in early development stages and costs are high. As more equipment is manufactured and improvements made, costs decrease. Gas frac service equipment is now available in most areas and costs currently are being adjusted downward in nearly all areas.

Costs of liquefied CO_2 and LPG are determined by availability in an area and transportation costs and are subject to seasonal fluctuations. The CO_2 is generally the most expensive component of the gas frac fluid. It is also readily available only in a few areas and usually must be transported great distances. This requires careful pre-job planning and coordination of material supply and adds to job cost. This problem has been overcome in some areas by the use of modified fluid systems which will be discussed later.

Another factor that has affected both costs and job performance adversely in the past has been the lack of properly equipped transport and storage tanks for the liquefied gases. Initially it was the practice to use highway transports both to haul the materials and store them on location. Since federal law restricts both size and number of outlets on over-the-road transports, these units have limited withdrawal rates. Thus, they tend to limit injection rates by their inability to deliver the fluids rapidly enough during a job. Mobile storage tanks, Fig. 1, have been built and are now available as part of the gas frac equipment set. These have adequate outlets and pumps for nearly any desirable rate. Since rapid withdrawal can create a pressure differential in the vapor space and cause collapse of these tanks, a heat exchange and repressuring system is provided in the well hook-up. This is shown in the schematic of a gas frac treatment hook-up in Fig. 2.

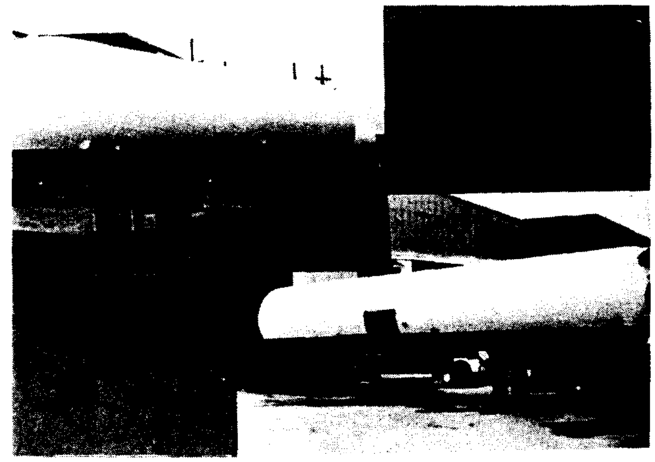

FIG. 1—FIELD STORAGE VESSELS DESIGNED TO SUPPLY LPG AND CO_2 AT INCREASED RATES

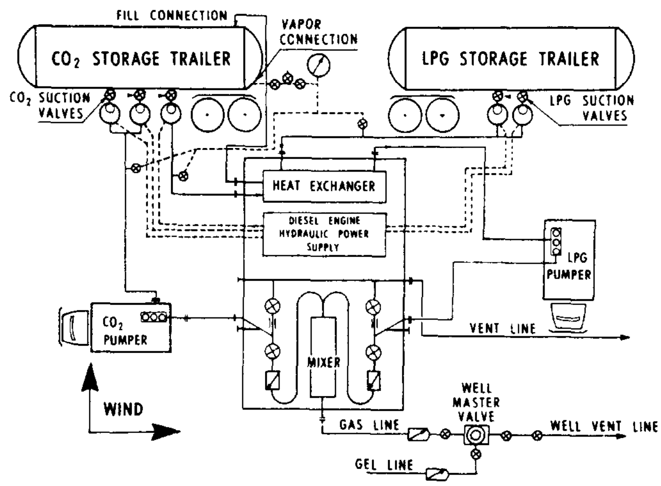

FIG. 2—SCHEMATIC OF EQUIPMENT HOOK-UP FOR GAS FRAC TREATMENT

MODIFIED GAS FRAC SYSTEMS

In some areas, gas frac has not provided economical productivity increases. That is, although the increases have been good, they have not been enough better than those provided by more conventional treatments to justify the added cost of a gas frac treatment. Still, results better than those with conventional treatments were desired, and modified gas frac systems were attempted. These modified systems vary according to area but two principal systems are in use at the present time. In the Farmington, New Mexico, area, a fluid made up of alcohol and LPG has been used with a high degree of success (Table 2), while a system using diesel oil and LPG has proved successful in the Oklahoma, South Texas, and East Texas areas (Table 2).

TABLE 2—RESULTS OF MODIFIED GAS FRAC TREATMENTS

State & County	Formation	Depth (feet)	Volume (gallons)	Avg Rate (BPM)	Treating Pressure (psi)	Prop Size	Prop Pounds	Daily Production Before	Daily Production After
Texas Brooks	Frio	5,440	18,000 (1)	8	4,300	20-40 10-20	20,000 12,000	1.7 MMCFD	2.7 MMCFD
Texas Harrison	Cotton Valley	10,660	24,000 (1)	15	5,500	20-40	30,000	No test	S.I.
Texas Webb	Olmo	7,200	29,000 (1)	10	6,500	20-40	56,000	No test	300 MCFD
Utah San Juan	Organrock	2,400	16,800 (2)	10	2,200	10-20	25,000	No test	1.5 MMCFD
New Mexico San Juan	Cliffhouse	4,000	5,000 (2)	6	1,000	20-40	6,000	No test	1.2 MMCFD

(1) Gelled oil - LPG

(2) Gelled alcohol - LPG

The success of the modified systems probably is due basically to the liquid content of the formations prior to treatment. Many formations undoubtedly contain higher water or oil saturations than are indicated by initial testing. As previously stated, wells with high water saturations are considered poor candidates for gas frac. However, in the case of the modified alcohol-LPG system, the formation water in wells with only moderate water saturation is probably compatible with the alcohol to aid in water removal[2] while the LPG would provide a more volatile component to aid in clean-up. A treatment of this type could well be justified inasmuch as cost is greatly reduced by elimination of the CO_2.

Where liquid hydrocarbon content of a formation may be higher than indicated by well testing, the diesel oil-LPG systems should prove effective. The gelled diesel oil would provide an effective fracture fluid and sand transport medium while the more volatile LPG would serve both as a solvent and dilution agent to aid in well clean-up. Again, cost is more compatible with results due to the elimination of the CO_2.

While the modified systems do not vaporize entirely in the formation as do the original gas frac systems, their use is dependent on the specialized equipment required for handling the volatile components and they are truly an outgrowth of the original systems. Furthermore, they provide a choice of fluids for use to meet varying reservoir characteristics as well as to justify the economics of the treatment.

FUTURE DEVELOPMENTS

Modified gas frac systems have minimized or eliminated the CO_2 component to justify use of the systems with moderate liquid saturations, either water or liquid hydrocarbons. An innovation now undergoing development is a fluid using only liquefied CO_2 and LPG for the dry gas reservoirs. In this system, where the alcohol is eliminated, the gelling agents, breakers and fluid loss agents are added directly to the liquefied gas mixture. Prop is added to the fluid by injecting it into the fluid stream under pressure equivalent to gas storage pressure. Such a system should provide the following advantages:

1. Reduced cost—Elimination of alcohol would not only save the cost of this material but would reduce handling and transportation cost.
2. A homogeneous fracture fluid—Elimination of the alcohol would also eliminate some of the mixing problems that occasionally occur when adding the alcohol gel to the liquefied gas mixture at the wellhead.
3. Better control of critical temperature—The increase in critical temperature of the gas frac fluid produced by the addition of the methyl alcohol would be eliminated. Control of the critical temperature would be more accurate.

Future equipment developments will center mainly on methods of handling the two-component fluid. This will require new or improved methods of injecting additives and prop into the liquefied gas mixture under pressure.

SUMMARY

Use of liquefied gases as fracture fluids for gas wells has proved highly successful since the introduction of this technique. Problems encountered during the development period have led to better materials, equipment and understanding of the process and to reduced costs.

One of the more important developments has been the ability to determine what wells are good candidates. Modified systems have been developed for use in wells that are poor candidates for the original gas frac systems. These systems widen the area of application for the technique and provide economical production increases for many wells which have not responded favorably to more conventional fluids.

A new system containing only liquefied gases currently is undergoing development for dry gas reservoirs. It is felt that this system will provide economically justifiable increases in wells which still have not responded favorably to any type of treatment. It is also felt that this system will provide even better increases in many of the reservoirs where gas frac has already proved successful.

REFERENCES

1. Hurst, R.E.: Use of Liquefied Gases as Fracture Fluids for Dry Gas Reservoirs, SPE 4116, presented at 47th Annual Fall Meeting, SPE of AIME, San Antonio, Texas, Oct. 8-11, 1972.
2. McLeod, H.O. and Coulter, A.W.: The Use of Alcohol in Gas Well Stimulation, SPE 1663, presented at the Eastern Regional Meeting, SPE of AIME, Columbus, Ohio, Nov. 10-11, 1966.