Gas Frac - A New Stimulation Technique Using Liquid Gases*

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INTRODUCTION

Many gas-bearing reservoirs have resisted stimulation from conventional methods of liquid injection. Expected stimulation results often are totally or partially offset because of liquid retention by the reservoir. Core testing on many reservoir rocks, especially those with pore structures displaying a high surface area (pin point porosity), verifies this type of damage.

Frequently, liquid retention damage was credited to water sensitivity when water, brine, or acid was used as the treating fluid. It is recognized that water sensitivity is a real problem and frequently adds to the complications associated with liquid retention. When oils were used in gas reservoirs with negative results, the problem was related to the creation of a third phase.

Without becoming involved in the academic merits of classifying negative stimulation results according to the aforementioned problems, a new stimulation fluid has been created which can be useful in the prevention of liquid retention and/or water sensitivity. For these reasons, this new fluid will have widespread application in gas reservoirs and to a lesser degree will prove its value in many oil wells. The new stimulation fluid is one composed of liquefied petroleum gases and liquefied carbon dioxide in varying volumetric proportions such that the resultant liquefied gas can be used to perform hydraulic work, then allowed to volatilize at reservoir producing conditions. This system is not to be confused with the previous work where carbon dioxide, nitrogen, or natural gas bubbles were dispersed in treating liquids, normally in the ratio of 50 to 1000 standard cubic feet per barrel, to provide assistance for flow-back.

Without the intention of limiting the discovery of combining liquefied petroleum gases with liquefied carbon dioxide to hydraulic fracturing procedures, we will, for simplicity, refer to the new fluid in this paper as Gas Frac and discuss how it is now being used as a hydraulic fracturing tool.

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GAS FRAC SYSTEMS

Liquefied petroleum gases can be acquired in several forms with the more common being propane, butane, and pentane or combinations. Each of these has its own critical temperature (critical temperature being defined as that temperature above which the material cannot exist as a liquid regardless of pressure). For most wells, the critical temperature of liquefied petroleum gases is high compared to well temperature, and when coupled with producing pressures, the petroleum gases would remain a liquid. Carbon dioxide has a relatively low critical temperature (approximately 88°F) and therefore is limited in its use as a hydraulic fracturing medium because it would volatilize too rapidly in hotter wells. When these common gases are mixed in predetermined ratios, the critical temperature can be controlled between the extremes of the individual components and thus provide a useful liquid for fracturing and a gas system for recovery. Figure 1 shows how liquefied carbon dioxide and liquefied petroleum gases can be mixed in volumetric proportions to obtain mixtures with various critical temperatures. In practice, a critical temperature of 1° to 25°F below the well temperature is assigned to the desirable mixture. With this critical temperature, the proper mixture for use in an individual well can be determined. For wells with BHT below 90°F, it is fortunate that corresponding reservoir pressures are usually low; here the Gas Frac systems can be chosen based on vapor pressure of system versus BHP. Choice of system is one with vapor pressure above BHP (Fig. 2).

GAS FRAC FLUID PROPERTIES

With a fluid system in hand which has potential

CARBON DIOXIDE - HYDROCARBON MIXTURES FOR GAS FRAC FLUIDS

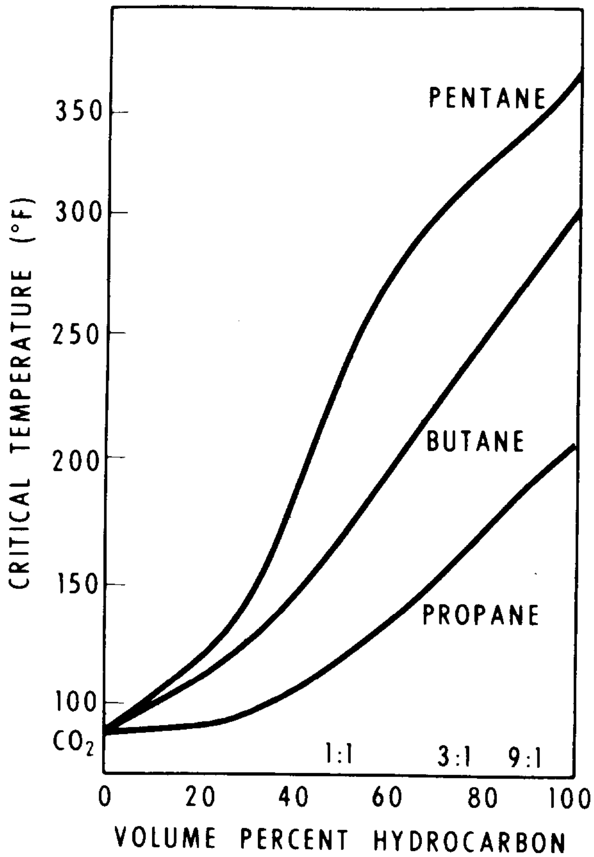

FIGURE 1

VAPOR PRESSURE OF PROPANE-CO_2 MIXTURES

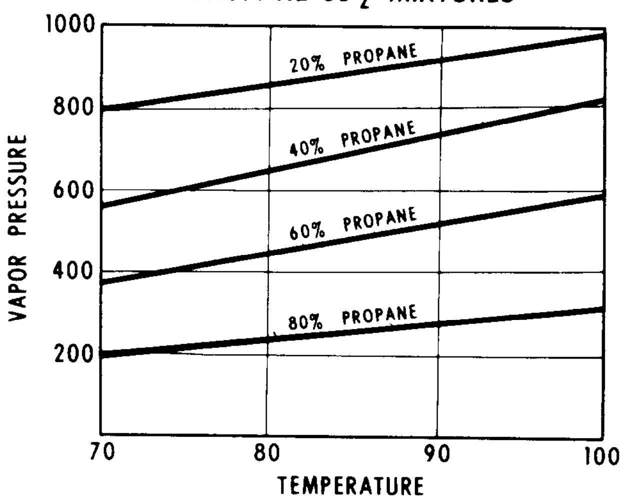

FIGURE 2

for solving many troublesome fracturing problems, it was necessary to impart certain properties to the system in order to gain the work effectiveness common to conventional systems which have been improved over the last twenty years. Fluid properties desired were: controllable viscosities, low leak-off or fluid loss control, low friction, and good prop-carrying ability. Most agents which were adaptable to water or oil systems were not effective in Gas Frac or were undesirable because of their residue. A family of proprietary compounds prepared in methyl alcohol has been found which imparts desirable characteristics to the system. Properties of Gas Frac containing these proprietary compounds are shown in Figs. 3, 4 and 5.

RHEOLOGY OF GAS FRAC SYSTEMS

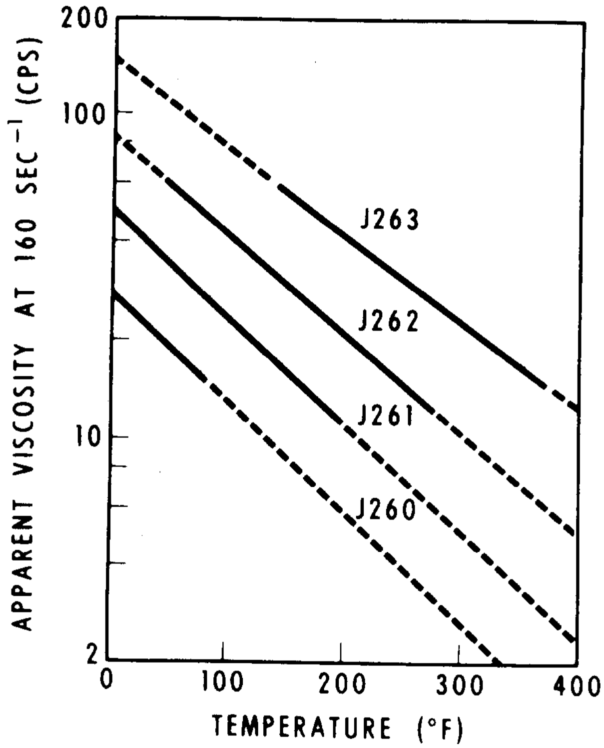

FIGURE 3

FLUID PROCUREMENT

Since the bulk of the new Gas Frac fluid is liquefied petroleum gas and/or liquefied carbon dioxide, both being readily available and often times a product of the well operator, economics dictate that arrangements for the delivery of these liquids be a function of the producer, just like the common procedure in oil or water fracs.

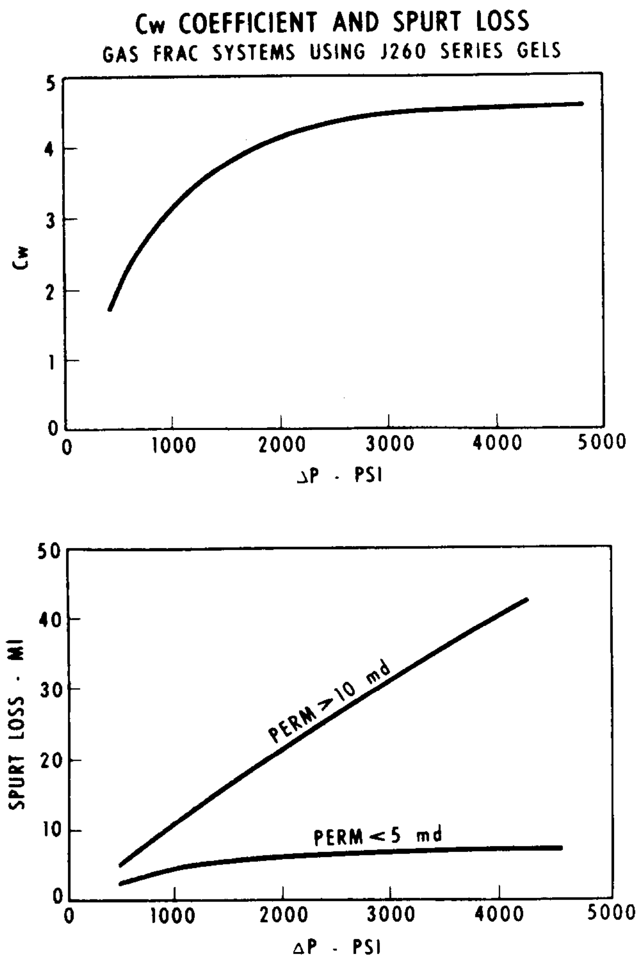

FIGURE 4

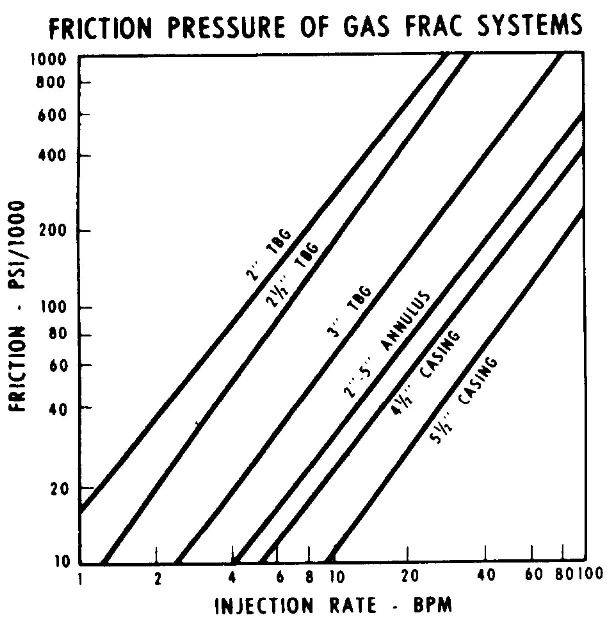

FIGURE 5

In certain instances, delivery can be arranged by the pumping service company on a cost plus basis. Supplies of liquefied carbon dioxide containing small amounts of impurities are sometimes available at reduced prices as compared to the commercially pure product. Generally, these small amounts of impurities are not detrimental to Gas Frac.

TRANSPORTATION AND FIELD STORAGE

Because of their volatile nature, all Gas Frac liquid components are delivered to well locations in closed vessels. When injection rates of 1 to 20 BPM are adequate, withdrawal can usually be made from the highway transport. Proper choice of LPG transports is necessary even at these low rates because of the excess flow valves installed in all over-the-road haulers. Special field storage vessels have been prepared with vaporizers to maintain vapor pressures and reduce line pressure drops in order that higher injection rates, in excess of 30 BPM, can be obtained. Since these are special vessels, they are supplied by the pumping service company. The controlled vapor pressure storage vessels serve another purpose in that they eliminate a decreasing temperature profile on the liquids, as occurs with withdrawal from the conventional highway transports. The loss of product from transports or field storage vessels is negligible during the time required to complete an operation; but where a specific job size is important, a 10 to 20 percent excess of carbon dioxide and petroleum gas is desirable to compensate for losses which can be encountered in securing a leakproof flow system test and elimination of system heat in warm climates. If the losses do not occur, the excess is then available to add to the job volume or to be returned to the supplier, if economical.

PUMPING OF GAS FRAC

All the base ingredients of Gas Frac present more safety considerations than most medium to low gravity oils, acid, brines, or water. For this reason, all pumping equipment is equipped with remote controls which allows removal of personnel to a safer position. The prop blending equipment used is a unique, dynamically closed system whereby props can be injected without escape of hazardous vapors (Fig. 6). Prop concentrations in the total system are limited depending upon the Gas Frac fluid required and the capability of currently available blenders. Normal concentrations of one-half to three pounds per gallon are easily provided. Concentrations of three to five pounds per gallon probably can be obtained for short periods with good planning. Before the Gas Frac system enters the well, all ingredients have been thoroughly mixed to provide proper critical temperature, viscosity, reduced leak-off, reduced friction, and distribution of props. Although all Gas Frac systems should be considered as flammable for safety planning, a good many contain sufficient carbon dioxide to greatly minimize this hazard.

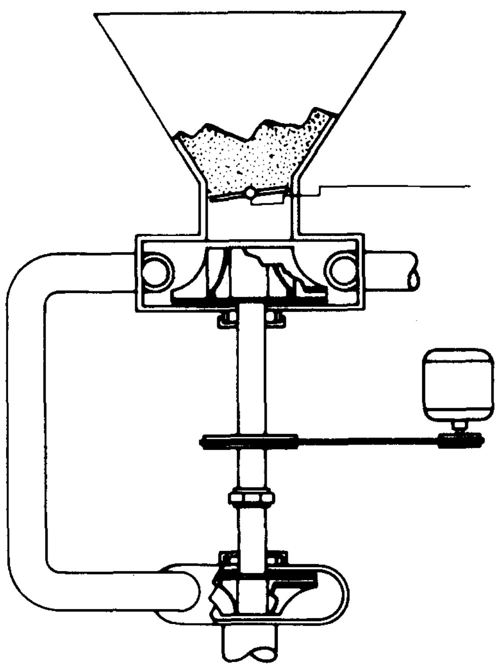

FIGURE 6

WELLHEAD CONTROLS

Gas Frac can be performed under most of the conventional tubular goods arrangements which are used in conventional completions designed for good safety. Jobs have been performed down tubing under packers, down casing, down annulus, and down tubing and annulus. One requirement which is impractical to reduce is that all well valves, wellhead equipment, and uncemented tubular goods have a working pressure in excess of maximum pressure to be encountered during the fracture operation. This special requirement is necessary due to the expansive nature of the Gas Frac systems which could build pressure during times of planned or emergency shut-down before venting can be safely performed. Wellhead hookups for injection and venting are unique and too detailed for individual application to be discussed in this paper.

ECONOMICS

Gas Frac is more expensive than crude, water, or brine fracs. The variance is due to several factors such as use of higher priced fluids, additional investment in specialized equipment, and current use of chemicals prepared in pilot plant operations. The costs involved in this new development are still less than those encountered with initial fracturing operations 20 years ago. It is only reasonable that with more concentrated use of the new process, certain cost positions can be and will be improved. The ultimate economic test will be decided by:

1. Increased well production
2. Decreased clean-up costs
3. Minimized liquid disposal.

RESULTS FROM GAS FRAC

Initial applications of Gas Frac in 1971 can largely be classified as research. More concern probably was placed on job performance ability and curiosity than adequate screening of wells to provide economical results. Even under these conditions, not unique to any new stimulation technique, Gas Frac has made its mark. Continued improvement in application choice, job design and job performance will undoubtedly prove Gas Frac a very useful tool in well stimulation activities.

Tables 1, 2 and 3 present results of 1971 applications as reported on early tests. Generally, these results can be classified as much better than other types of treatments in these reservoirs.

TABLE 1

GAS FRAC RESULTS*
MID-CONTINENT AREA

FORMATION SYSTEM	APPROX DEPTH	FRAC VOLUME	FRAC RATE-PRESSURE	PIPE SIZE	FOLDS INCREASE
PENNSYLVANIAN	6500	15000	16-4000	2½	24
CRETACEOUS	9500	15000	11-7000	2	

*PRODUCTION -FIGURES NOT RELEASED

TABLE 2

GAS FRAC RESULTS*

WEST TEXAS AREA

FORMATION SYSTEM	APPROX DEPTH	FRAC VOLUME	FRAC RATE-PRESSURE	PIPE SIZE	FOLDS INCREASE
PENNSYLVANIAN	1500	13000	12-1000	4½	58
PENNSYLVANIAN	3000	13000	12-1300	4½	20
PENNSYLVANIAN	6000	21000	12-3800	2½	64
PENNSYLVANIAN	6000	30000	18-5000	2½	15
PENNSYLVANIAN	6000	21000	16-6000	2½	10
PENNSYLVANIAN	6500	30000	18-5500	2½	15
PENNSYLVANIAN	6500	30000	16-5000	2½	

*PRODUCTION FIGURES NOT RELEASED

TABLE 3

GAS FRAC RESULTS*

ROCKY MTS. - CANADA AREA

FORMATION SYSTEM	APPROX DEPTH	FRAC VOLUME	FRAC RATE-PRESSURE	PIPE SIZE	FOLDS INCREASE
CRETACEOUS	1000	13000	12- 800	4½	18
TERTIARY	2500	13000	12-1500	2½	20
CRETACEOUS	3000	22000	18-2500	2½	5
CRETACEOUS	4000	22000	13-4000	2½	5
CRETACEOUS	5000	20000	12-2500	2½	8
CRETACEOUS	6000	21000	11-4500	2½	15
CRETACEOUS	8000	25000	18-2800	4½	30
CRETACEOUS	9000	22000	11-4500	2/5½	25

*PRODUCTION FIGURES NOT RELEASED

CONCLUSIONS

Gas Frac is a fracturing treatment using liquefied petroleum gas and liquefied carbon dioxide as the base fracturing fluid. It was developed primarily for gas wells and provides the following advantages:

1. Prevents formation damage resulting from liquid retention and/or water sensitivity
2. Greatly reduces clean-up time and minimizes liquid disposal since treating fluids are returned as gases
3. Provides better stimulation ratios than conventional fluids and techniques.

The basic ingredients for Gas Frac are more hazardous than some of the conventional fluids, but the hazards have been greatly reduced by special equipment, techniques, and careful safety planning.

Although the cost of Gas Frac treatments is somewhat higher than that of conventional treatments, the economics appear favorable due to greater production increases, reduced clean-up time and minimum liquid disposal. More concentrated use of the new process in the future will undoubtedly improve the cost position.