# RESPONSE OF ANTON-IRISH CLEARFORK CRUDE TO MISCIBLE DISPLACEMENT TESTS

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## ABSTRACT

Approximately fifty billion barrels of stock tank oil were originally in place in the large carbonate reservoirs of the Permian Basin. Two-thirds of this oil occurred in the San Andres and Grayburg strata. Much of the recent work utilizing carbon dioxide as the miscible displacing fluid has been conducted in San Andres reservoirs, yet other strata may also offer substantial opportunities. Ten to fifteen percent of the original oil-in-place was reported to be in Clearfork or Yeso reservoirs.

One of the large Clearfork producers in West Texas is the Anton-Irish oil field. The estimated original oil in place was near 500 million barrels. The cumulative production to 1/1/84 was 150 million barrels. This leaves more than 300 million barrels of stock tank oil as a possible target for a successful EOR project. If the EOR project should recover as much as fifteen percent of the original oil-in-place this would increase the oil recovery by 75 million barrels of stock tank oil. Hence the purpose of this work was to conduct a laboratory study to determine the response of a Clearfork crude oil to different miscible displacement oil recovery processes. Carbon dioxide gas was used as the displacing fluid on one series of tests, and LPG slugs pushed by nitrogen were used in a second series of tests. This paper reports the results of the study.

## INTRODUCTION

The carbonate reservoirs in the Permian Basin of West Texas and Southeast New Mexico offer a tremendous opportunity for enhanced oil recovery programs by miscible displacement with carbon dioxide. Gruy[1] recently reported that approximately fifty billion barrels of stock tank oil were originally in place in the large carbonate reservoirs of the Permian Basin. Two-thirds of this oil was in the San Andres and Grayburg strata. Much of the recent work with carbon dioxide has been conducted in San Andres reservoirs, yet other reservoirs may also offer substantial opportunities. Ten to fifteen percent of the original oil-in-place was in the Clearfork or Yeso stratum. The Clearfork name is used in Texas, and Yeso is used for the equivalent geologic stratum in New Mexico.

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One of the large Clearfork producers in West Texas is the Anton-Irish oil field. The Anton-Irish field was discovered some forty years ago and covers an area of 9000 acres. The thirty degree API gravity crude produces from the Clearfork formation, an oolitic dolomite. The Clearfork is described as averaging 8.5 percent porosity, permeability of 7 to 19 md and with 400 ft of gross and 140 feet of net pay. The estimated original oil-in-place was near 500 million barrels. The cumulative production to 1/1/84 was 150 million barrels. This leaves more than 300 million barrels of stock tank oil as the target for a successful EOR project. If the EOR project should recover fifteen percent of the original oil-in-place this would increase the oil recovery by 75 million barrels of stock tank oil. Hence, the purpose of this study was to determine the response of a Clearfork crude oil to different displacing fluids. Carbon dioxide gas was used as the displacing fluid in one series of tests and LPG slugs, pushed by nitrogen were used in a second series of tests.

Considerable work has been presented on the displacement of several crudes by carbon dioxide[2][3][4]. The work by O'Leary, et al, showed that $CO_2$ miscibility on Levelland Sand Andres crude might be expected at pressures near 1400 psi and reservoir temperature of 105°F.[2]. The displacement of Wasson San Andres crude with $CO_2$ resulted in miscibility at a slightly lower pressure.

The work of Fischer, et al, reported on the displacement of the North Cowden and Goldsmith crudes[3]. In that work it was demonstrated that a fractionation process took place when crude oil was displaced by carbon dioxide. A clear or straw-colored liquid formed between the crude oil and the $CO_2$. This clear slug had more of the light hydrocarbon components than the original crude. Reference (4) cites results of studying an Ellenburger crude oil.

## EQUIPMENT AND PROCEDURE

The laboratory study was conducted using a slim tube 40 ft in length packed with unconsolidated media to represent the reservoir matrix. The coiled pack was placed in a constant temperature oil bath. The cleaned and evacuated pack was filled with the stock tank crude oil at the desired reservoir pressure and temperature. No gas was in solution. When displacing the crude oil with carbon dioxide, the gas was injected at the desired temperature and displacement pressure from the beginning to the end of the test.

When LPG was used as the displacing fluid, a five percent HCPV (hydrocarbon pore volume) slug of LPG was injected followed by nitrogen gas through the end of the test. An analysis of the LPG is shown in Table I.

Oil recovery was measured in a separator and recorded as percent original oil-in-place (%OOIP) at gas breakthrough and at the ultimate recovery of 30,000 to 1 gas-oil ratio (GOR). The experiment was terminated when the 30,000 to 1 GOR was measured by a wet test meter. The equipment was cleaned with a solvent, evacuated, resaturated with the crude at the desired run pressure, and a successive run initiated.

Cleaning the pack was especially important to eliminate the heavy, second phase which apparently accumulated on the porous media for this particular crude oil-carbon dioxide system. The heavy liquid phase was not so pronounced for the crude oil - LPG nitrogen system.

## RESPONSE TO CARBON DIOXIDE

Using the Anton-Irish crude, tests were made to observe the effect of reservoir pressure on oil recovery by the injection of carbon dioxide. Oil recovery tests were made at 112°F and 250°F. The actual reservoir temperature is near 112°F.

Figure 1 shows the effect of pressure on oil recovery when displacing the Anton-Irish crude with 100 percent carbon dioxide at 112°F. The stock tank crude had no gas in solution. It can be seen from the figure that when displacing the crude at a pressure of 750 psi the oil recovery at gas breakthrough was approximately 56 percent of the original oil-in-place. The ultimate recovery was found to be just over 76 percent at a producing gas-oil ratio of 30,000 to 1.

By increasing the displacement pressure to 2000 psig the oil recovery was 92 percent at gas breakthrough, and the ultimate oil recovery at a 30,000 to 1 GOR was over 98 percent of the original oil-in-place.

Figure 2 shows the effect of pressure on oil recovery when displacing the Anton-Irish crude with 100 percent carbon dioxide at a reservoir temperature of 250°F. This figure shows that when using a displacement pressure of 1600 psi, the oil recovery at gas breakthrough was 48 percent and the ultimate oil recovery was near 71 percent at a producing GOR of 30,000 to 1.

By increasing the displacement pressure to 3500 psi, the oil recovery at gas breakthrough was 94 percent of the original oil-in-place and nearly 96 percent of the original oil-in-place was ultimately recovered at a 30,000 GOR.

## RESPONSE TO LPG SLUGS

Tests were made to observe the effect of reservoir pressure on oil recovery when displacing the Anton-Irish crude with a five percent hydrocarbon pore volume slug of LPG pushed by nitrogen. The composition of the LPG is shown in Table I. The tests were conducted at 112°F. From Figure 3 it can be seen that when displacing the crude at 2000 psi the oil recovery was near 53 percent at gas breakthrough and increased to over 88 percent at a producing gas-oil ratio of 30,000 to 1. By increasing the displacement pressure to 3000 psi the oil recovered at gas breakthrough was near 85 percent. The ultimate oil recovery at a 30,000 GOR was over 98 percent of the original oil-in-place.

Figure 4 illustrates the effect of displacement pressure on oil recovery when displacing the same crude sample by a five percent HCPV LPG slug pushed by nitrogen at 250°F. It can be seen that when using a displacement pressure of 1500 psi, less than 37 percent of the oil was

recovered at gas breakthrough. The oil recovery was near 68 percent at a 30,000 GOR. By increasing the displacement pressure to 2000 psi the oil recovery at gas breakthrough increased to 94 percent, and the ultimate recovery was near 98 percent at a 30,000 GOR. Increasing the displacement pressure to 3000 psi increased the oil recovery at gas breakthrough to near 96 percent and increased the ultimate recovery to in excess of 98 percent.

## PRESSURE-TEMPERATURE RECOVERY RELATIONSHIP

Figure 5 shows a summary of oil recovery data for the Anton-Irish crude. These data illustrate the conditions for approximately 90 percent oil recovery as a function of pressure and temperature for both carbon dioxide and LPG slugs pushed by nitrogen as the displacing fluid. It can be seen in this figure that the reservoir pressure required to achieve miscibility with carbon dioxide increases with temperature, but the reservoir pressure required to achieve miscibility with LPG decreases with temperature.

When carbon dioxide was used, the required pressure for 90 percent oil recovery increased from 1880 psi to 3040 psi as the temperature increased from 112°F to 250°, respectively. See Figure 5.

When five percent HCPV LPG slugs are used, the pressure required decreases from 3300 psi to 2000 psi for temperatures ranging from 112° to250°F, respectively. Note that for low temperature reservoirs the use of carbon dioxide to achieve miscibility may be effective at pressures on the order of 1400 psi below the pressure required when using 5 percent HCPV LPG slugs. For high temperature reservoirs the use of LPG slugs to achieve miscibility may be effective at pressures as much as 1000 psi below the pressure required when using carbon dioxide.

## SUMMARY

Laboratory studies have been made to study the oil recovery by miscible displacement of the 31° API gravity Anton-Irish Clearfork crude oil. Both carbon dioxide and LPG slugs pushed by nitrogen were used for the displacing fluids. Two temperatures of 112°F and 250°F were studied.

It was found that a pressure of 1880 psi was required to achieve miscibility (defined as 90 percent oil recovery at gas breakthrough) when using carbon dioxide as the displacing fluid and a temperature of 112°F. By contrast approximately 3040 psi was required to achieve miscibility when displacing the crude oil at 250°F with carbon dioxide.

When using carbon dioxide as the displacing fluid it was found that the miscible displacement pressure increased more than a thousand psi as the reservoir temperature increased from 112° to 250°. The reverse was true when using LPG slugs as the displacing fluid.

The crude oil was displaced with a five percent HPV slug of LPG pushed by nitrogen. At a temperature of 112°F it required a pressure of 3300 psi to achieve a 90 percent oil recovery at gas breakthrough. When the temperature was increased to 250°F it required a pressure of 2000 psi to achieve a 90 percent oil recovery at gas breakthrough.

It was found that the reservoir temperature had a very substantial effect on the miscibility pressure. At high reservoir temperatures, LPG slugs pushed by nitrogen were effective at pressures 1000 psi less than the pressure when using $CO_2$. At lower reservoir temperatures the reverse was true, i.e., $CO_2$ achieved a 90 percent oil recovery at a pressure 1000 psi less than LPG slugs.

The miscibility pressure of this Clearfork crude was found to be a few hundred psi greater than the miscibility pressure of the San Andres crudes previously studied. This may be attributed to a slightly higher temperature for the Clearfork crude, a lower API gravity and a different chemical composition. These laboratory results apply to the actual reservoir fluid only to the extent that the crude sample studied is representative of the actual reservoir fluid at rock conditions.

## REFERENCES


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## ACKNOWLEDGMENTS


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Table 1
LPG Slug Composition

Gas Chromatograph Analysis of LPG or "Propane" Slug Showed the Following Composition

| | Mol Percent |
|---|---|
| Propane | 91.958 |
| Iso-butane | 2.023 |
| N-butane | 1.372 |
| Ethane | 4.347 |
| $CO_2$ | 0.104 |
| $C6^+$ | 0.0019 |
| Iso-pentane | 5.822E-02 |
| Methane | 5.572E-02 |
| Nitrogen | 3.928E-02 |
| Oxygen | 1.455E-02 |
| N-pentane | 2.657E-02 |

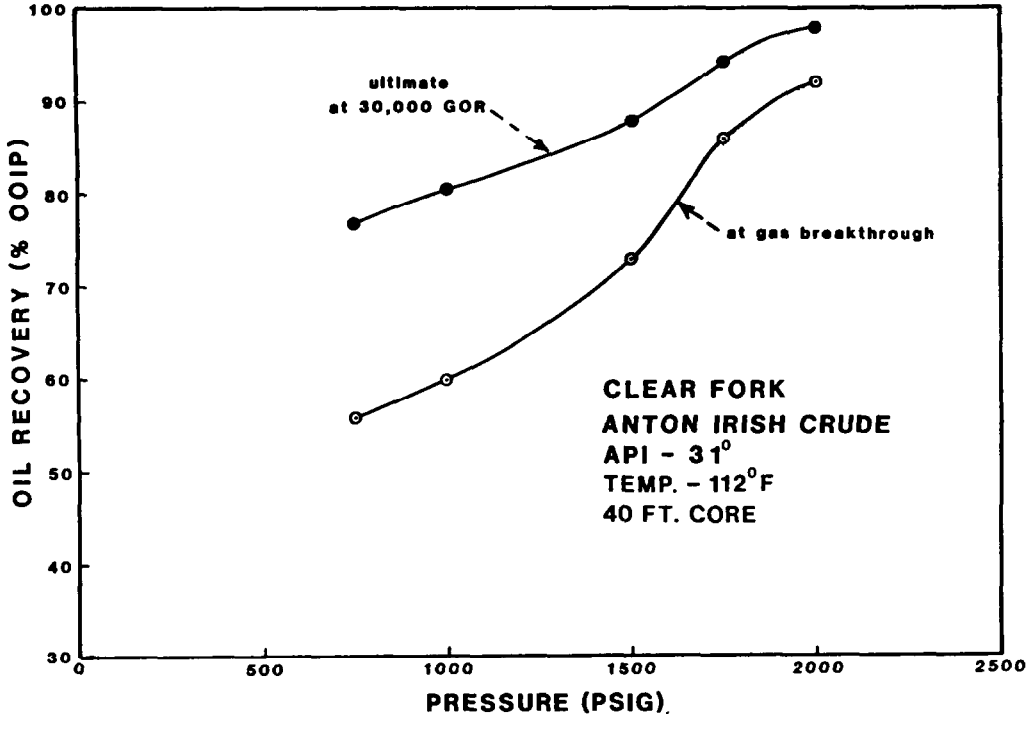


Figure 1—Oil recovery using 100% $CO_2$

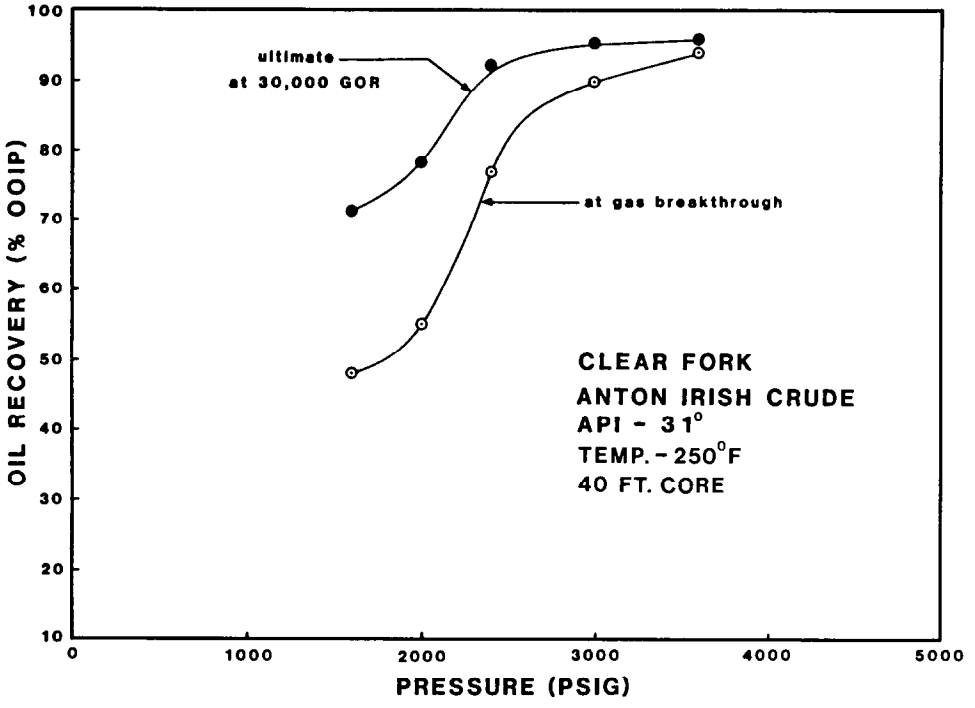


Figure 2—Oil recovery using 100% $CO_2$

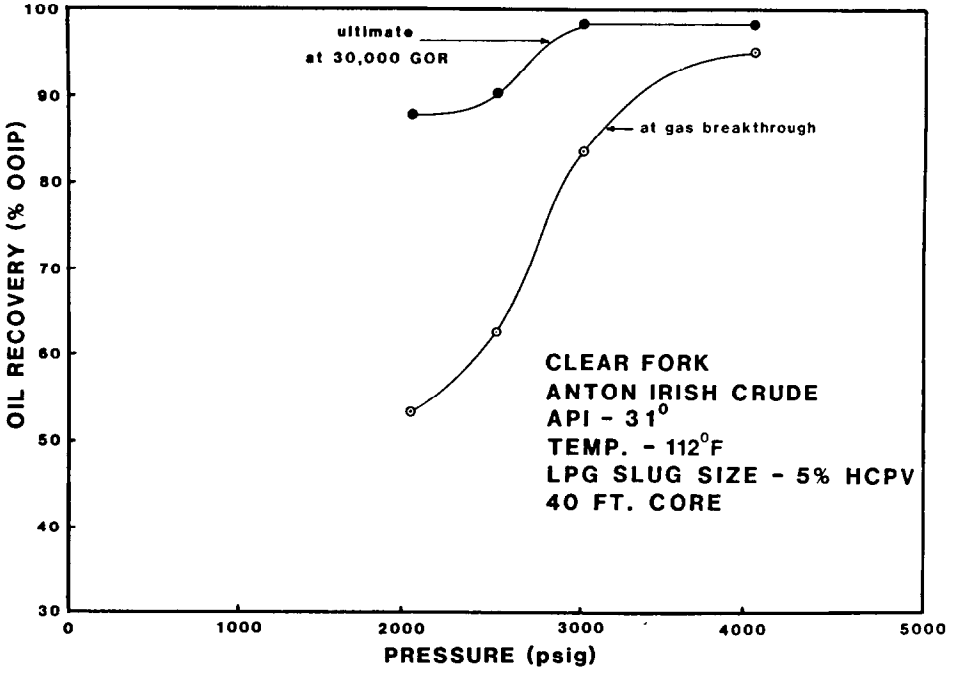


Figure 3—Oil recovery using LPG slugs pushed by nitrogen

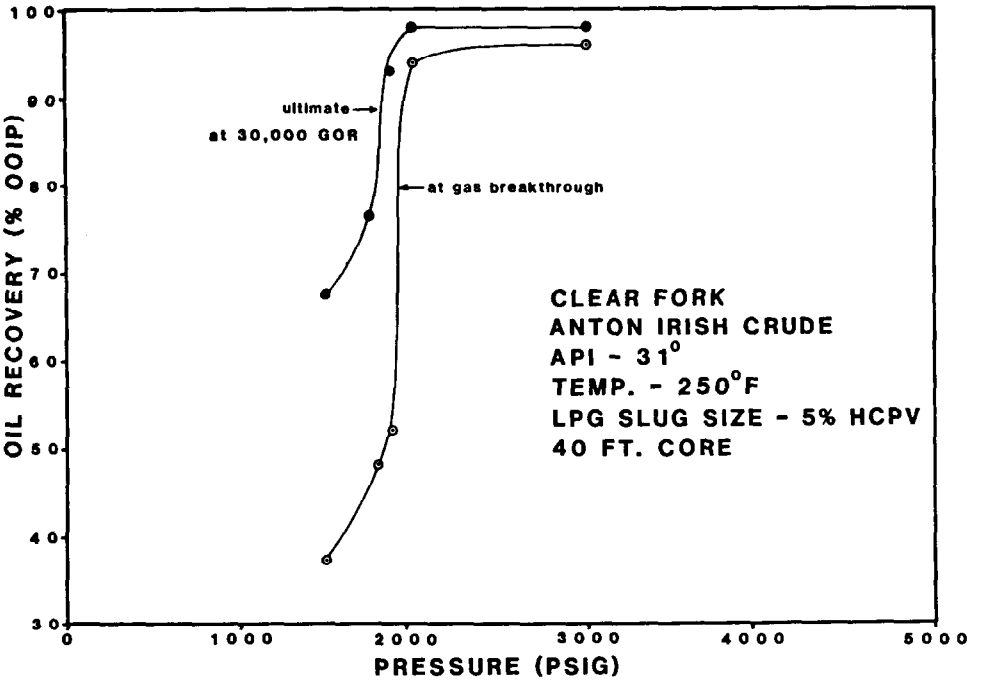


Figure 4—Oil recovery using LPG slugs pushed by nitrogen

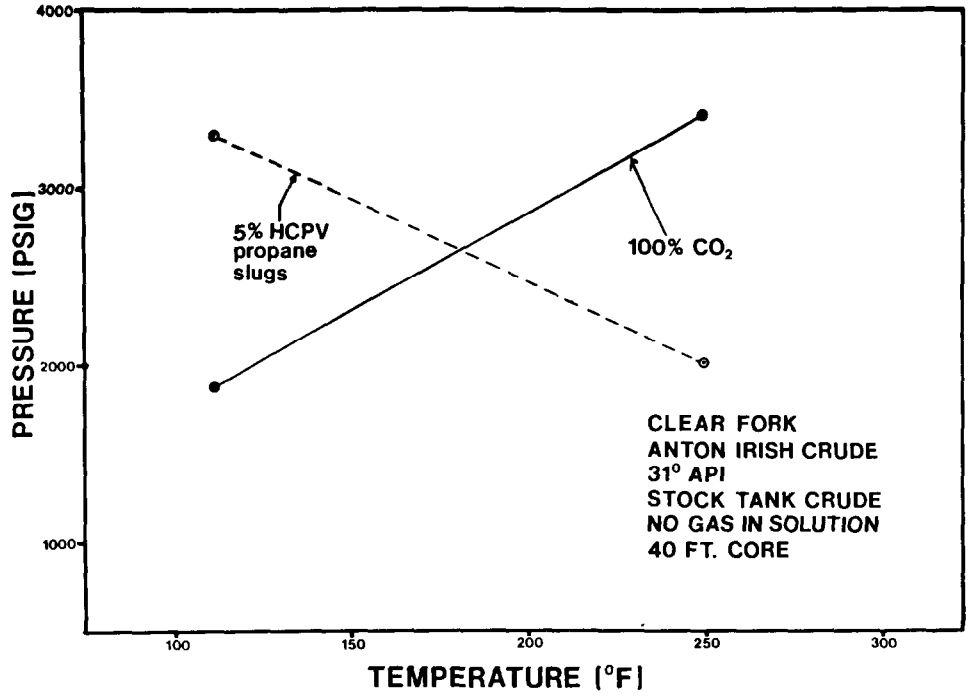


Figure 5—Crossplot of 90% oil recovery for both 100% $CO_2$ and LPG slugs pushed by nitrogen