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RESEARCH ARTICLE

EVALUATION OF PARAMETERS THAT AFFECT MINIMUM MISCIBILITY PRESSURE DURING GAS INJECTION PROCESSES

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Abstract

The application of (CO2) miscible gas displacement at a minimum miscible pressure causes the reduction of fluid viscosity and lowers the interfacial tension between the reservoir fluid and injected gas thereby enhancing maximum fluid recovery at the time when the reservoir energy is stunted.

There are usually parameters that affect the minimum miscibility pressure (MMP) in such way that gas and reservoir fluids are mixed together in single homogeneous phase. These parametersas discussed herein are analyzed using PVTi, Eclipse 300 simulation software. The software utilized Peng-Robinson equation of state model (PR3) to create an injection environment and analyze necessary parameters that affect MMP.

The simulation results showed that MMP increases as temperature increases and decreases as reservoir fluid composition moves from light to heavy fluid. Observations also showed that MMP increases with increase in mole percent of injected gas (CO2). It is therefore important to effectively analyze and control parameters affecting MMP in order to achieve maximum recovery of reservoir fluid, dependent on operators' discretions.

Introduction:-

Several schemes are usually considered and or adopted to improve oil recovery from reservoirs at times when the primary energy of the reservoir can no longer support economic recovery. The term 'Enhanced Oil Recovery' principally refers to the recovery of oil by any method beyond the primary stage of oil production through processes that help to increase the primary reservoir drive. These processes may include pressure maintenance, injection of displacing fluids or other methods, such as thermal techniques. Therefore, by definition, EOR techniques include all methods that are used to increase the cumulative oil produced (oil recovery) as much as possible.

In immiscible gas injection, flooding by gas is conducted below MMP. This low pressure injection of gas is used to maintain reservoir pressure to prevent production cut-off, and thereby increase the rate of production. The combination of light crude, relatively high reservoir temperature and relatively low reservoir pressure favours immiscible gas injection.

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In miscible gas injection, the gas is injected at or above MMP, which causes the gas to be miscible in the oil. This study focused more on the miscible gas injection (Carbon dioxide injection).

It is well known that the amount of GHG (greenhouse gases) especially CO2 in the atmosphere has resulted in climate change and global warming which are big concerns for human comfort in recent years. There are number of ways to reduce the amount of CO2 in the atmosphere, one of which is CO2 geological sequestration in oil reservoirs. Researchers have discussed that this method cannot only minimize the concentration of CO2 in the atmosphere, but can also improve additional oil recovery by CO2 flooding as a method of Enhanced Oil Recovery.

The main mechanisms of oil recovery by CO2 injection has been identified as;

- Reducing viscosity of oil
- Swelling the crude oil
- Lowering the interfacial tension between the oil and the CO2/Oil phase in the miscible regions
- It also produces miscibility since it has lower MMP and solubility process.

The basic parameter for determining if Carbon dioxide injection can be applied for an oil field is its minimum miscibility pressure (MMP) which can be estimated through computations and experiments such as slim-tube experiments, mixing-cell experiments, rising bubble/falling drop experiments, and vanishing interfacial tension experiments.The MMP is the lowest pressure for which a gas can develop miscibility through a multi-contact process with a given reservoir oil at the reservoir temperature.Miscibility can be either be in form of first contact miscibility (FCM) or multi contact miscibility (MCM). First contact miscibility (FCM) refers to the state when the fluids reach miscibility with the first contact between them; while MCM refers to the state which fluids reach miscibility after several contacts.

Gardner in 1981; Holm and Josendal in 1982; Harmon and Grigg in 1988; Turek in 1988; Creek and Sheffield in 1993 had established that MMP depends on the composition of the crude oil and injected gas, and temperature of the fluids. In 2012, Yanfurther noted that pressures higher than minimum miscibility pressure achieves recovery expected to reach 100% in microscopic scale.

Study Objective:-

- The study aimed at investigating the parameters that affect the lowest pressure (minimum miscibility pressure) which gas (CO2) will be miscible when injected into a reservoir fluid for optimum fluid recovery while using PVTI software/ platform.

Scope of Study:-

Reservoir fluid properties and phase was established on PVTi platform

Research Approach:-

Generally, the injection of gas into the reservoir results in an increased production. However different parameters affect the rate of miscibility of gas with oil such as reservoir fluid composition, injection gas composition, temperature, density of the reservoir fluid and C+ mole weight. In this study, these parameters wereevaluated to determine its effects on MMP.

Fluid Characterization and Generation of PVT Tables:-

To obtain the PVT properties of different hydrocarbons, PVTi software based on Peng-Robinson Equation of State Model was used. Multiple Equation of State (EOS) models exist defining the pressure, temperature and volume (PVT) relationship of fluids but Peng-Robinson equation of state model generates MMP at multi-contact miscibility. The PVT data was added to the main simulator for injection study experiment, i.e., Eclipse 300 as the simulation software package then PVTi as sub program for carrying out injection study.

Different gas compositions were used to perform these simulations at a multi-contact test. For each gas composition the simulations were performed with a specific temperature to obtain the effects of gas composition and temperature variation on MMP.

Different pure hydrocarbons were also used to perform injection study simulations at multi-contact to obtain the effects of reservoir fluid variation.

Injection of gas into Reservoir Fluid at Different Temperature:-
Gas was injected into the reservoir fluid in a multi contact miscibility test at different temperature to obtain the effects of temperature on MMP.

The properties of CO2 and the hydrocarbon used in this simulation are shown in Table 1.0 below at temperature of 500◦ k, 450◦ k, 400◦ k, 380◦ k, 350◦ k, 330◦ k, 300◦ k, 250◦ k, 200◦ k, 150◦ k and 144◦

Table 1.0:- Reservoir Fluid and Injected Gas Composition.

COMPONENT	RESERVOIR FLUID MOL %	INJECTION GAS MOL %
N2	2.81	12.5
CO2	0.51	75,4
C1	75.5	6.5
C2	7.92	4.6
C3	4.82	1
IC4	1.13	0
NC4	1.54	0
IC5	0.59	0
NC5	0.52	0
C6	0.50	0
C7	1.51	0
C8	0.79	0
C9	0.73	0
C10	0.23	0
C11	0.20	0
C12	0.18	0
C13	0.13	0
C14	0.12	0
C15	0.07	0
C16	0.05	0
C17	0.04	0
C18	0.03	0
C19	0.02	0
C2O+	0.06	0

Different Gas Composition injected at Constant Temperature:-
Injecting different gas composition in the same fluid composition at a constant temperature of 490◦ was performed to check the effect of gas composition on MMP.

Table 2.0:- Summary of different Gas Composition Injected at Constant Temperature of 490° k.

COMPONENT	RESERVOIR FLUID (MOLE %)	INJECTION GAS (MOLE %)								
		M1	M2	M3	M4	M5	M6	M7	M8	M9
CO2	38	32	56.5	64.5	72	76	85	92	98.5	100
C1	26	29.8	19.6	9.2	12.8	5.5	6.3	2.1	0.2	0
C2	3	22.4	12.5	18.8	4.1	6.5	2.1	1.1	0.2	0
C3	3	12.6	2.2	4.3	4	3.5	1.1	2.4	0.1	0
C4	3	3.1	6.2	2	4.1	2.5	3.5	1.4	0.5	0
IC4	3	0.1	3	1.2	3	6	2	1	0.5	0
NC4	3	0	0	0	0	0	0	0	0	0
IC5	3	0	0	0	0	0	0	0	0	0
NC5	3	0	0	0	0	0	0	0	0	0
C6	3	0	0	0	0	0	0	0	0	0
C7+	15	0	0	0	0	0	0	0	0	0

From Table 2.0, it can be seen that all the gases were injected at the same reservoir fluid and the resultant density of fluid, mole weight of fluid and concentration of CO2 were tabulated and plotted to check the effect of these parameters on MMP as will be shown in the result.

Different Reservoir Fluid Simulated at Constant temperature and Injection Gas:-
Different pure hydrocarbons also were used to perform injection test at multi-contact miscibility to obtain the effects of reservoir fluid variation at constant temperature of 550◦ k. See Tables 3.0 and 4.0 below.

Table 3.0:- First Reservoir Fluid and Injected Gas Composition at Temperature of 550◦ k.

COMPONENTS	RESERVOIR FLUID MOLE %	INJECTED GAS MOLE %
N2	3.42	0.2
CO2	0.62	98
C1	38.2	0.6
C2	18.2	0.1
C3	16.1	0.4
IC4	3.62	0.7
NC4	2.42	0
IC5	1.32	0
NC5	2.50	0
C6	1.50	0
C7+	12.1	0

Table 4.0:- Second Reservoir Fluid and Injected Gas Composition at Temperature of 550◦ k.

COMPONENTS	RESERVOIR FLUID MOLE %	INJECTED GAS MOLE %
N2	0.10	0.2
CO2	0.62	98
C1	44.99	0.6
C2	16.64	0.1
C3	13.41	0.4
IC4	0.82	0.7
NC4	3.05	0
IC5	2.51	0
NC5	1.37	0
C6	1.85	0
C7+	14.64	0

Table 5.0:- Summary of Reservoir Fluid and Injected Gas Composition

COMPONENTS	RESERVOIR FLUID MOL %			INJECTION GAS MOL %
	Z1	**Z2**	**Z3**	
N2	3.42	0.10	2.38	0.2
CO2	0.62	0.62	0.57	98
C1	38.2	44.99	52.49	0.6
C2	18.2	16.64	8.10	0.1
C3	16.1	13.41	8.18	0.4
IC4	3.62	0.82	2.64	0.7
NC4	2.42	3.05	3.42	0
IC5	1.32	2.51	1.33	0
NC5	2.50	1.37	1.05	0
C6	1.50	1.85	0.89	0
C7+	12.1	14.64	18.95	0

Results and Analysis:-
After the simulation runs and considering its sensitivity nature to temperature, injected gas composition, reservoir fluid composition and C7+ mole weight the results obtained are as shown below;

Effects of Temperature:

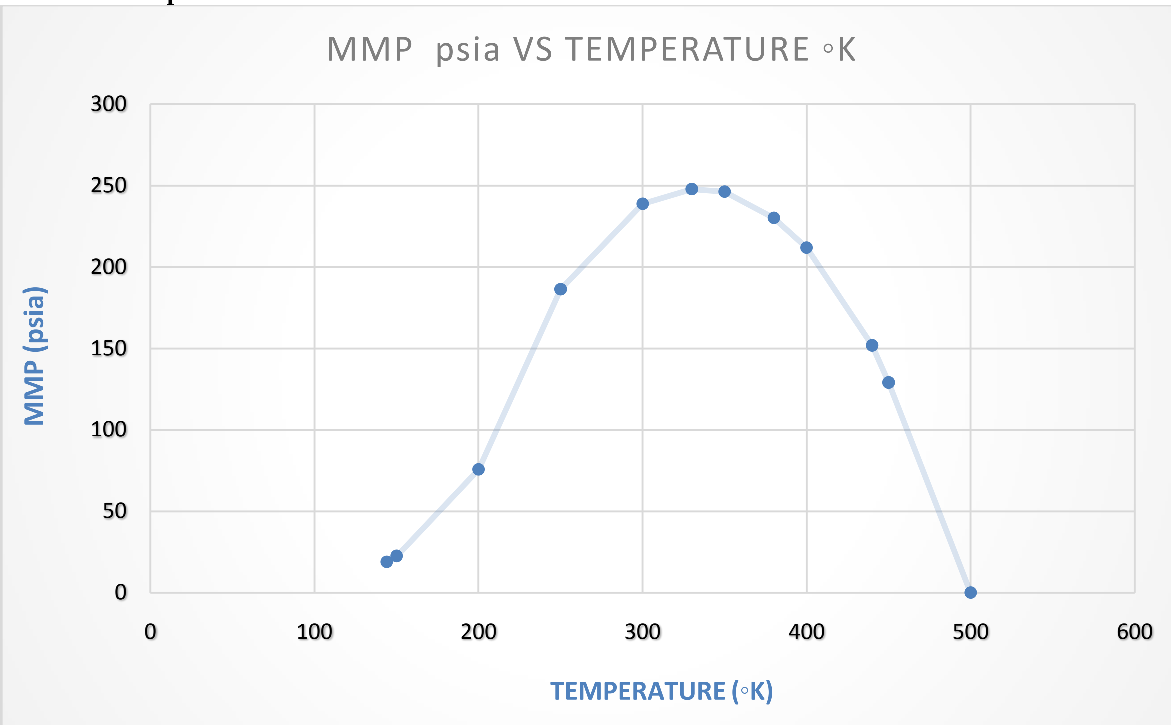

Figure 1:- The Effect of temperature on MMP

From the graph, at temperature below 144◦k and above 500◦k the MMP is equal to zero or cannot be determined. At temperature of 330◦k MMP have its maximum value of 247.7751psia. This thereforeshows thattemperature has great effect on MMP and can be altered in order to increase or decrease MMP.

Effects of Injected Gas Composition:

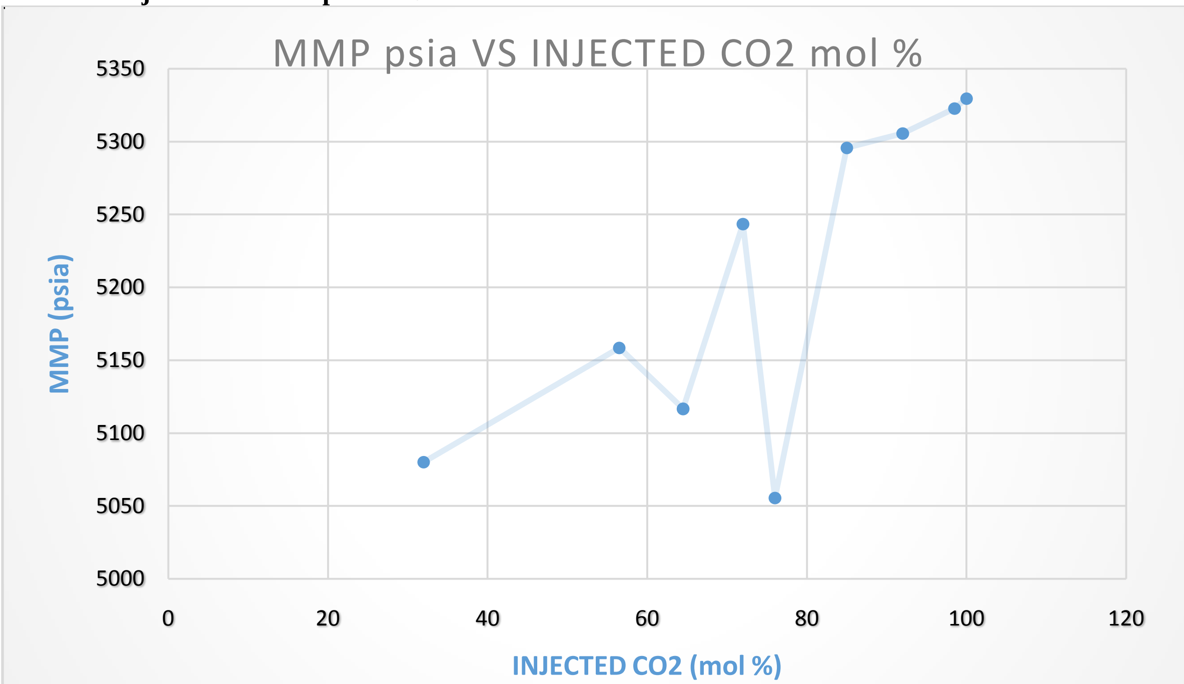

Figure 2:- The Effect CO2 Composition on MMP

There is an observed sudden drop of MMP at 76% mole concentration of CO2 and continuous increase until 100% CO2 concentration. It implies that at 100% concentration of injected gas, highest value of MMP is achieved.

Effects of Mole Weight and Density:

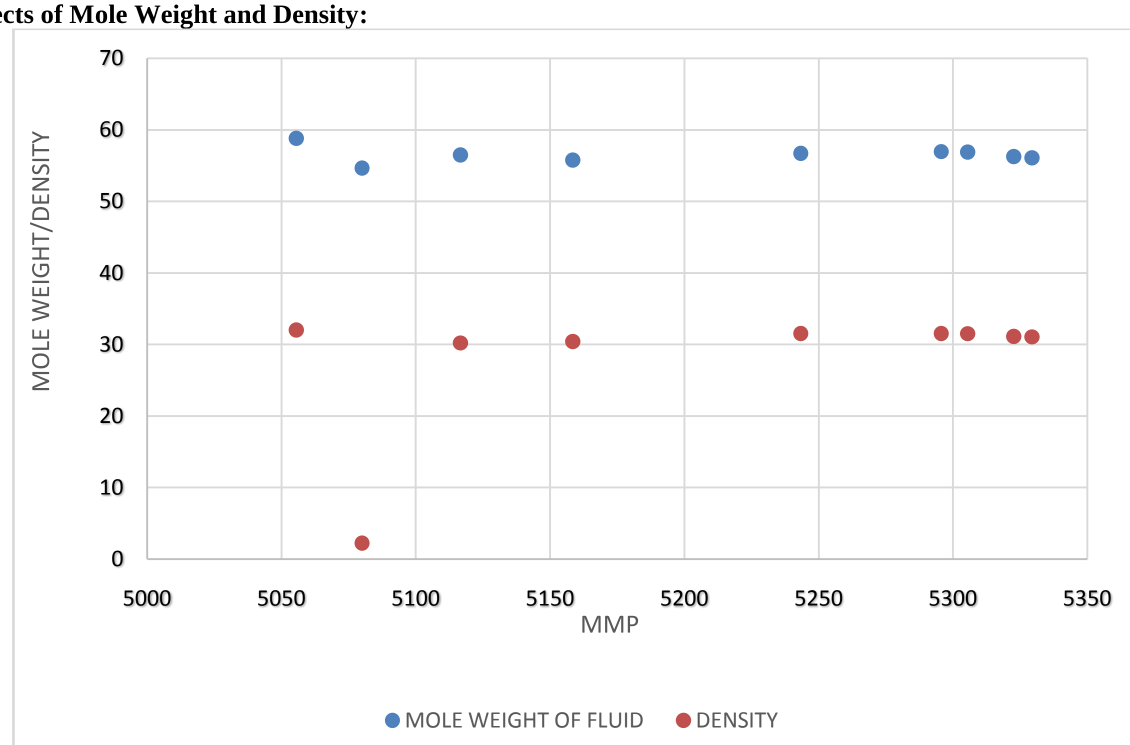

Figure 3:- The Effect of Fluid Mole Weight and Density on MMP

From the graph it shows that fluid mole weight and density have low effect on MMP, as both parameter increases as MMP increases.

Effects of Reservoir Fluid Composition:

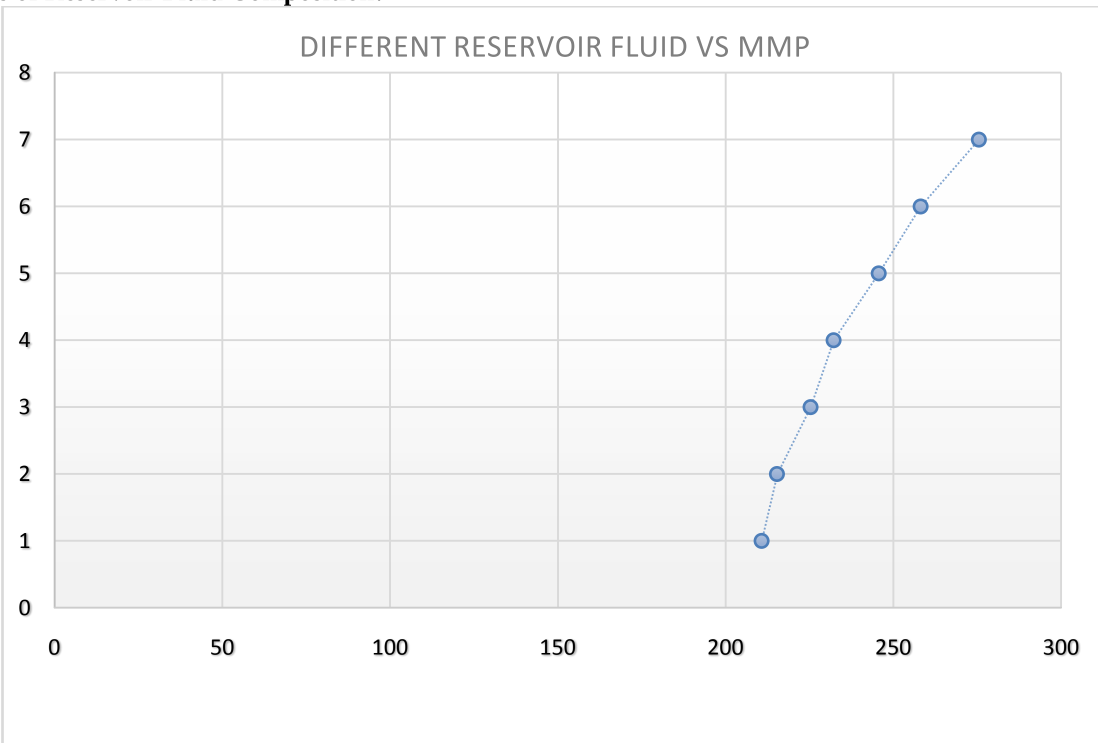

Figure 4:-Effects of Reservoir Fluid Composition on MMP

Reservoir fluid injected ranges from crude with C1 of 38.2 to 75.6 mole percent which implies heavy fluid to more volatile or light fluid. This implied therefore that lighter fluid has higher MMP than heavy crude. There will be higher CO2 displacement in lighter fluid.

Effects of C7+ Mole Weight:

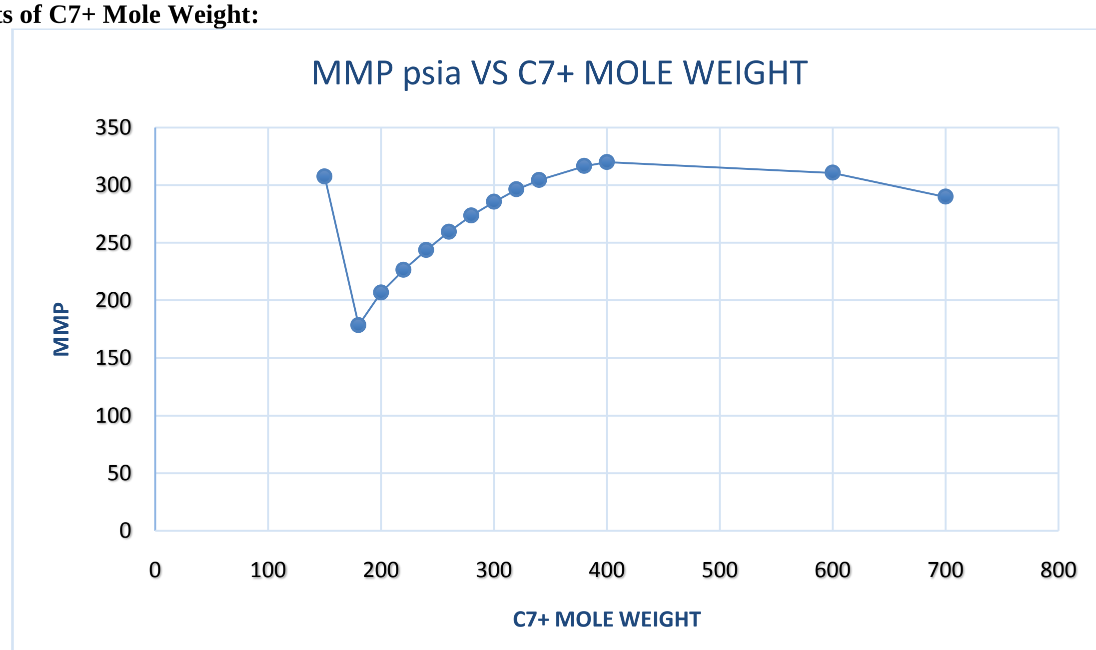

Figure 5:- The Effects of C7+ Mole Weight on MMP

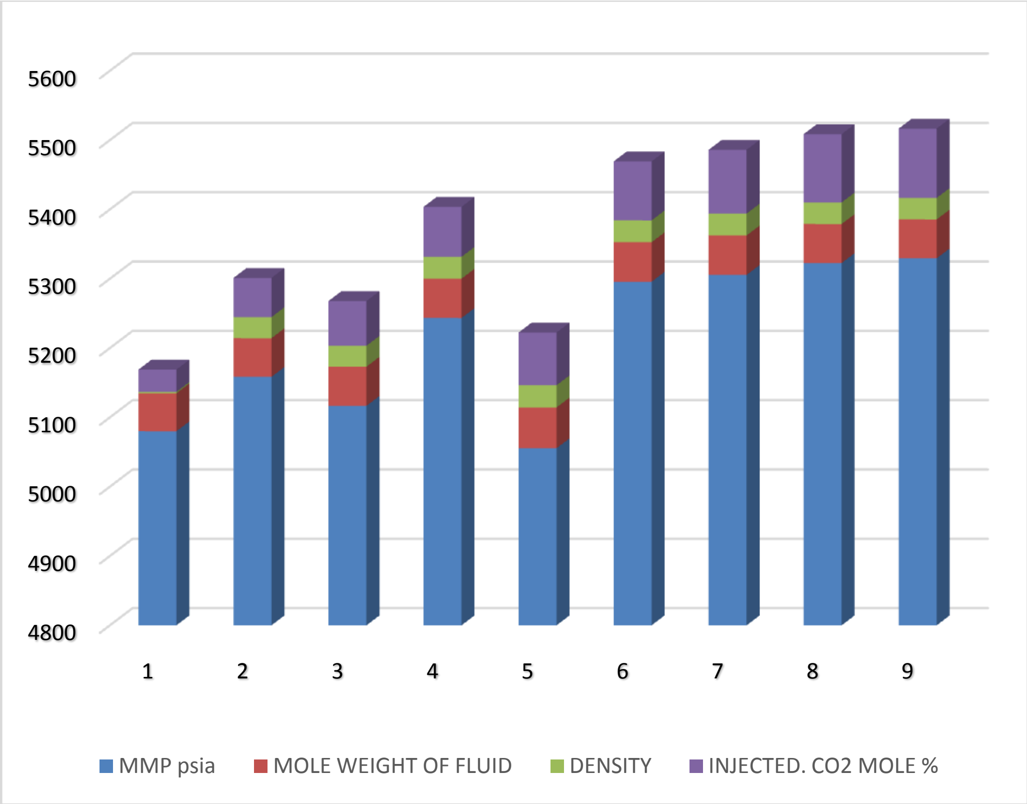

Figure 6:- The Combined Effect of Mole Weight of Fluid, Density and Injected Gas

Conclusion:-

From this study, it has been established that:-

- Temperature has high effect on the minimum miscibility during CO2 injection
- Composition of the injected gas affects the MMP
- Composition of the reservoir fluid affects the MMP
- C7+ mole weight affects the MMP
- Density and reservoir fluid mole weight have row effects on MMP

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