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Comparison of The Performance of Drag Reducing Agent Between 2.5 Cp Oil And 6.0 Cp Oil in Multiphase Flow in Horizontal Pipes

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ABSTRACT

Experimental studies have been performed in a 10 cm diameter, 36 m long, multiphase flow loop to examine the effect of drag reducing agents using 6 cP oil. Studies were performed for superficial liquid velocities of 0.5, 1.0 and 1.5 m/s and superficial gas velocities between 2 and 12 m/s. Carbon dioxide was used as the gas phase. The drag reducing agent (DRA) concentrations were 20 and 50 ppm. The system was maintained at a pressure of 0.13 MPa and a temperature of 25 °C. The comparison of the conditioning of flow with DRA between 2.5 cP oil and 6 cP oil is presented.

The results show that pressure drop in both 2.5 cP oil and 6 cP oil was reduced significantly in multiphase flow with addition of DRA. A DRA concentration of 50 ppm was more effective than 20 ppm DRA for all cases.

As the oil viscosity was increased from 2.5 cP to 6 cP oil, the transition to annular flow was observed to occur at lower superficial gas velocities.

For slug flow and lower superficial gas velocities, the effectiveness in 2.5 cP oil was much higher than that in 6 cP oil with addition of DRA. However, for higher superficial gas velocities, the effectiveness in both oils was similar. For annular flow, the effectiveness in 2.5 cP oil was higher than in 6 cP oil with 50 ppm DRA.

At low superficial gas velocities, DRA in 2.5 cP oil was more effective in reducing the slug frequency. This led to a higher average pressure drop reduction in 2.5 cP oil. However, at higher superficial gas velocities, the slug frequency decreased in both oils almost the same magnitude.

NOMENCLATURE

ΔP	= Pressure drop, Pa
ID	= Inside diameter, m
DRA	= Drag reducing agents
ASTM	= American Society Testing Material
Vsl	= Superficial liquid velocity, m/s
Vsg	= Superficial gas velocity, m/s
ppm	= Parts per million
$\Delta P_{w\,DRA}$	= Pressure drop without the presence of DRA, Pa
$\Delta P_{no\,DRA}$	= Pressure drop with the presence of DRA, Pa
V_{DRA}	= Volume of the DRA to be added
C_{DRA}	= Desired DRA concentration (ppm)
V_{total}	= Total liquid volume of the system

INTRODUCTION

Initially, most oil wells contain only oil and gas. The multiphase mixture is transported through a single multiphase pipeline from the well to a separation facility. During the transportation, several types of flow regimes exist and slug flow is the most common of all the flow regimes. In slug flow condition, the main problems are a large decrease in pressure and a large increase in corrosion rate. These problems can be controlled with the addition of drag reducing agents.

DRAs are long chain polymers, which prevent the bursts that create turbulence in the core. They interfere with the turbulence from being formed, or reduce the degree of turbulence. The use of drag reducing agents in single and multiphase pipelines is of great interest in the oil and gas industry since higher production can be obtained with the addition of a small amount of DRA.

Most of the drag reduction studies have been performed for single-phase flow using water-soluble DRAs such as polyacrylamide and polyethelyne oxide. Field tests using crude oil in Trans Alaska pipeline Systems and Iraq-Turkey pipelines have been reported by Burger [1] and Motier [2], respectively. An effectiveness of up to 30% in both pipelines was obtained with the use of oil-soluble DRA.

For multiphase flow, few papers have been reported (e. g. Greskovich, [3]; Rosehart, [4]; Sylvester, [5], [6]; Otten, [7]; Sifferman, [8]; kale, [9]). However, these works have been carried out in small diameter pipelines using water and air.

Kang and Jepson have found that using DRA in multiphase flow has many benefits. For example, adding DRA shifts the transition to the slug flow regime to higher liquid velocities [10]. In slug flow, the corrosion rate decreases by decreasing the slug frequency when DRA is added in the pipeline [11]. DRA works not only frictional pressure drop but also accelerational pressure drop in the slug flow regime [12].

The effect of DRA on the average pressure drop and slug characteristics in 2.5 cP oil/carbon dioxide gas in horizontal pipes was presented by Kang [13]. Here it was reported that the average pressure drop reduction of 82% for slug flow and 47% for annular flow was achieved. It was also shown that the flow pattern changed from slug flow to wavy stratified flow by decreasing the slug frequency from 8 to 0 slugs/minute when 50 ppm DRA was added.

Experimental studies have been performed to examine the effect of drag reducing agents in 6 cP oil. In this paper, a comparison of the conditioning of the flow with DRA between 2.5 cP oil and 6 cP oil is presented.

The definition of DRA effectiveness is to increase in pumpability of a fluid by adding certain polymers in turbulent flow [14]. The effectiveness of DRA can be calculated as follows:

$$\text{Effectiveness of DRA (\%)} = \frac{\Delta P_{no\,DRA} - \Delta P_{w\,DRA}}{\Delta P_{no\,DRA}} \times 100$$

EXPERIMENTAL SETUP AND TEST MATRIX

The experimental layout of the flow loop is shown in Figure 1. Oil is stored in a 1.2 m^3 stainless steel storage tank, which is equipped with a 3.8-KW heater and 6-m long (2.5 cm ID) stainless steel cooling coils to maintain a constant temperature. The 6 cP oil from the storage tank is then pumped into a 10-cm ID PVC pipeline by means of a 76 HP very low shear progressing cavity pump. Varying the speed of the pump using a variable-speed controller controls the liquid flow rate.

Carbon dioxide gas is stored in a 20,000 kg storage tank and introduced into the system at an inlet pressure of 2 MPa. The carbon dioxide gas is then regulated and the gas flow rate is measured using a variable area flow meter.

The oil/gas is mixed at a tee junction and then flows into an 18 m long Plexiglass pipeline where the pressure drop, flow pattern and slug frequency are measured. The pressure drop is measured along a 4.7 m length of the pipeline using pressure tappings connected to pressure transducers. The oil/gas mixture then returns to the storage tank and gas is vented through oil/gas separator to the atmosphere.

A high-speed camera and high-resolution monitor are used to record flow images, which are used for the determination of slug frequency.

The experiments were conducted in horizontal pipes at a system pressure of 0.13 MPa and at temperature of 25 °C. Oil with a viscosity of 6 cP was used as the liquid phase, whereas carbon dioxide was the gas phase. Superficial liquid velocities from 0.5 to 1.5 m/s and superficial gas velocities from 2 to 12 m/s were studied. This range of superficial liquid and gas velocities includes three flow patterns such as slug flow, pseudo-slug flow and annular flow. Oil-soluble DRA was used for the study. The DRA effectiveness was tested for 0, 20 and 50 ppm concentrations.

The DRA concentration is calculated on a total volume basis as follows:

$$V_{DRA} = \frac{C_{DRA} \times V_{total}}{1 \times 10^6}$$

RESULTS AND DISCUSSIONS

At a superficial liquid velocity of 0.5 m/s, the comparison of the average pressure drop with no DRA is shown in Figure 2. It can be seen that the average pressure drop for 6 cP oil was slightly greater than that for 2.5 cP oil as expected. For example, at a superficial gas velocity of 2 m/s, the average pressure drop was 1015 Pa and 1043 Pa in 2.5 cP and 6 cP oils, respectively.

At a superficial gas velocity of 8 m/s, pseudo-slug flow was observed in both oils. It was noticed that the pseudo-slug flow sometimes appears to become unstable since a large number of waves are present and the liquid film begins to spread around the pipe wall. In this case, the pressure drop is more due to changes in acceleration than due to friction.

At superficial gas velocities of less than 10 m/s, annular flow was observed. However, it should be noted that oil viscosity has an effect on the transition. As the oil viscosity was increased from 2.5 cP oil to 6 cP oil, the transition to annular flow was observed to occur at lower superficial gas velocities.

Figure 3 shows the comparison of effectiveness with 20 ppm DRA concentration. It is seen that at superficial gas velocities of less than 4 m/s, the effectiveness in 2.5 cP oil was much higher than that in 6 cP oil. For example, at a superficial gas velocity of 2 m/s, the effectiveness of DRA in 2.5 cP oil was 65%, while 38% in 6 cP oil. Here, the slug frequency in 2.5 cP oil decreased more, which led to higher effectiveness. At higher superficial gas velocities, the effectiveness for slug flow in both oils was similar. For annular flow, the effectiveness of DRA in 2.5 cP oil was higher than that in 6 cP oil. At a superficial gas velocity of 10 m/s, the effectiveness was 25% and 13% in 2.5 cP and 6 cP oils, respectively. It can also be seen that for slug flow, the effectiveness of DRA in both oils decreased with increasing superficial gas velocity. In 2.5 cP and 6 cP oils, the effectiveness decreased from 65% to 22% and from 38% to 17%, respectively.

Further increasing DRA concentration to 50 ppm was accompanied with more reduction in the average pressure drop in both oils. Figure 4 shows the comparison with 50 ppm DRA at the same conditions. The same trend was observed for slug and annular flow. At a superficial gas velocity of 2 m/s, the effectiveness of up to 75% in 2.5 cP oil was achieved since the flow pattern in 2.5 cP oil was changed from slug flow to stratified flow. The effectiveness of DRA for slug flow in both oils was over 30%.

At a superficial liquid velocity of 1.5 m/s, the comparison of the average pressure drop with no DRA is shown in Figure 5. The slug flow regime in 2.5 P oil was noticed at superficial gas velocities up to and including 10 m/s. At higher viscosity oil, the slug flow regime was observed at superficial gas velocities of less than 10 m/s. It can be seen from Figures 2 and 5 that increasing superficial liquid velocity from 0.5 to 1.5 m/s in both oils was accompanied by an increase in the average pressure drop at each superficial gas velocity. For example, the average pressure drop in 6 cP oil increased from 1152 Pa to 3280 Pa and from 1701 to 4030 Pa at superficial gas velocities of 4 and 6 m/s, respectively. This is due to the fact that the height of the liquid film increases with increasing superficial liquid velocity and this leads to higher slug frequency. This phenomenon has been found by many researchers (R. J. Wilkens, [15]; Jepson and Taylor, [16], etc.).

Figure 6 shows the comparison with 20 ppm DRA at the same conditions. It can be seen that at superficial gas velocities of less than 4 m/s, the effectiveness in 2.5 cP oil was much higher than that in 6 cP oil when 20 ppm DRA was added. However, at higher superficial gas velocities, the effectiveness for both slug flow and annular flow in both oils was similar. For annular flow, the effectiveness of DRA in both oils was less than 6%.

Increasing DRA concentration to 50 ppm led to more effectiveness in all cases as shown in Figure 7. For example, at superficial gas velocities of 2 and 12 m/s, the effectiveness in 2.5 cP oil was 60% and 18%, respectively. At the same gas flow rates, the effectiveness in 6 cP oil was 41% and 9%, respectively.

Figures 8 and 9 show the comparison of slug frequency with 20 and 50 ppm DRA at a superficial liquid velocity of 0.5 m/s. It can be seen that the slug frequency in both oils generally decreased significantly with addition of 20 and 50 ppm DRA concentrations. It is also seen that increasing DRA concentration to 50 ppm led to a greater decrease in the slug frequency. At low superficial gas velocities, DRA in 2.5 cP oil was more effective in reducing the slug frequency, which led to higher average pressure drop reduction in 2.5 cP oil. However, at higher superficial gas velocities, the slug frequency decreased in both oils almost the same magnitude. Here, the effectiveness in both oils was similar. As noted earlier, decreasing the slug frequency leads to a decrease in the average pressure drop, leading to an increase in DRA effectiveness. It can be seen from both Figures that at lower superficial gas velocities, the DRA in both oils was more effective for the slug frequency reduction. For example, at a superficial gas velocity of 2 m/s and 50 ppm DRA, the slug frequency decreased from 8 to 0 slugs/minute and from 12 to 5 slugs/minute in 2.5 cP and 6 cP oil, respectively. At a superficial gas velocity of 6 m/s and the same DRA concentration, the slug frequency decreased from 14 to 9 slugs/minute and from 12 to 10 slugs/minute in 2.5 cP and 6 cP oil, respectively.

Figures 10 and 11 show equivalent plots at a superficial liquid velocity of 1.0 m/s. It can be seen from Figures 8 and 10 that the slug frequency at a superficial liquid velocity of 1.0 m/s is much higher than that at a superficial liquid velocity of 0.5 m/s in all cases. For example, at a superficial gas velocity of 4 m/s and liquid velocities of 0.5 and 1.0 m/s, the slug frequencies in 6 cP oil were 11 and 26 slugs/minute. This is due to the fact that the height of the liquid film increases with an increase in superficial liquid velocity, which leads to an increase in slug frequency.

Very similar results were noticed with the presence of DRA. The slug frequency decreased significantly in all cases. At lower superficial gas velocities, DRA in both oils was more effective in reducing the slug frequency.

CONCLUSIONS

Experiments have been carried out to test the effectiveness of DRA in a 10 cm I.D. multiphase flow pipeline. The comparison of the conditioning of flow with DRA between 2.5 cP oil and 6 cP oil in horizontal pipes has been presented.

At 0 ppm DRA, the average pressure drop for 6 cP oil was slightly greater than that for 2.5 cP oil.

As the oil viscosity was increased from 2.5 cP oil to 6 cP oil, the transition to annular flow was observed to occur at lower superficial gas velocities.

A DRA concentration of 50 ppm DRA was more effective than 20 ppm for all cases. At low superficial gas velocities and all superficial liquid velocities, the effectiveness in 2.5 cP oil was much higher than that in 6 cP oil. However, at higher superficial gas velocities, the effectiveness for both slug flow in both oils was similar.

At all superficial liquid and gas velocities, the slug frequency in both oils decreased significantly with addition of 20 and 50 ppm DRA concentrations

At low superficial gas velocities, the DRA in 2.5 cP oil was more effective in reducing the slug frequency, which led to a higher average pressure drop reduction in 2.5 cP oil. However, at higher superficial gas velocities, the slug frequency decreased in both oils almost the same magnitude.

Decreasing the slug frequency leads to a decrease in the average pressure drop leading to an increase in DRA effectiveness.

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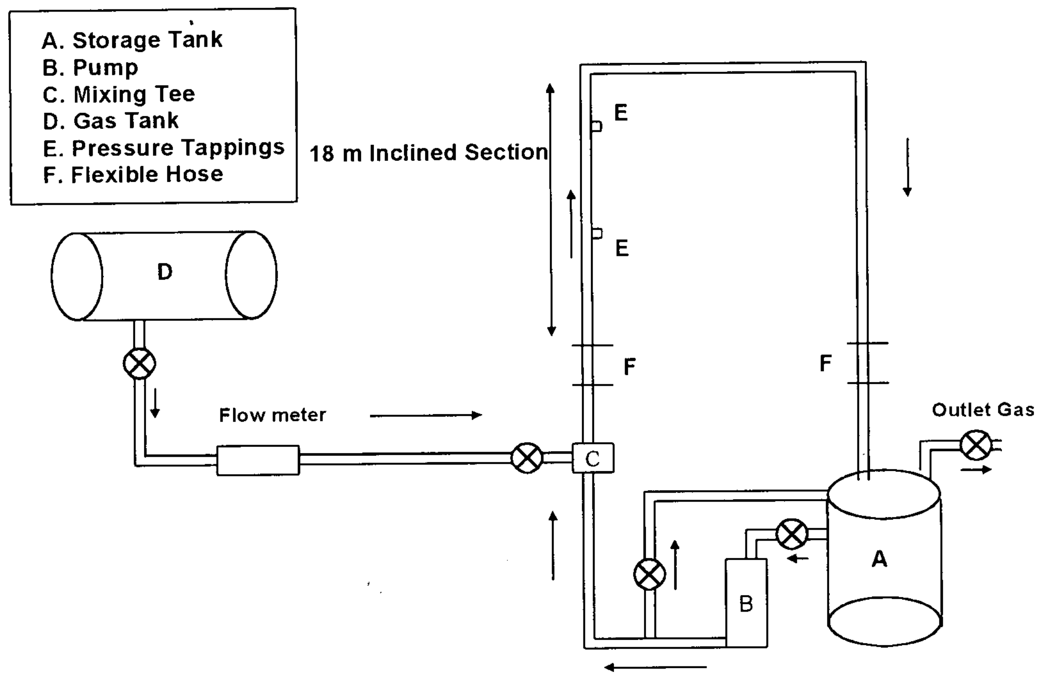
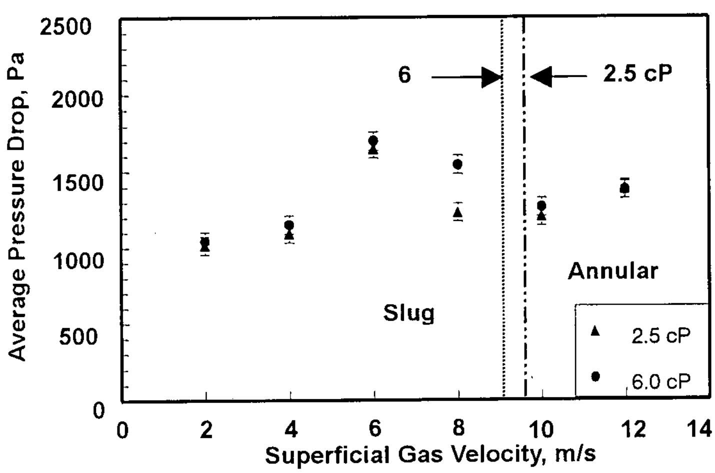


Figure 1. Experimental Layout of the Flow Loop



Fiaure 2. Comparison of the Average Pressure Drop
Vsl = 0.5 m/s, 0 ppm DRA, Horizontal Pipes

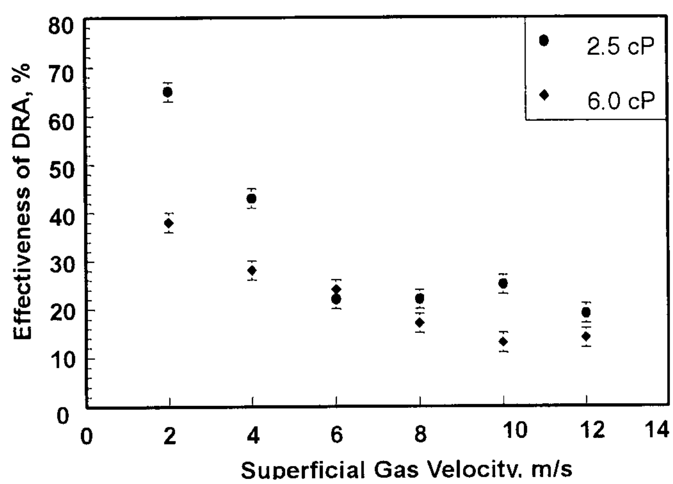


Figure 3. Comparison of Effectiveness of DRA
Vsl = 0.5 m/s, 20 ppm DRA, Horizontal Pipes

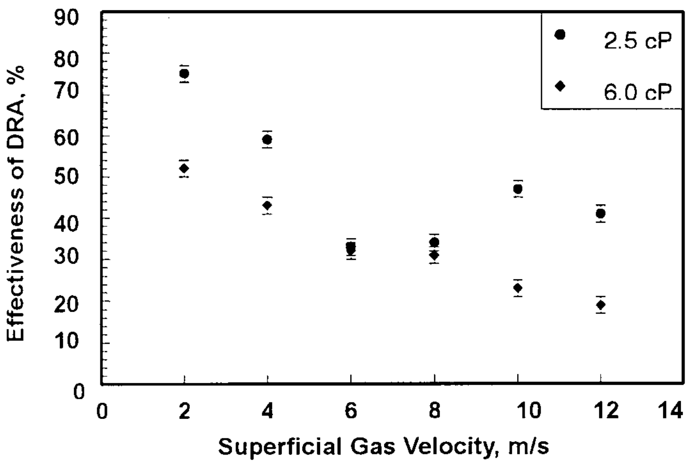


Figure 4. Comparison of Effectiveness of DRA
Vsl = 0.5 m/s, 50 ppm DRA, Horizontal Pipes

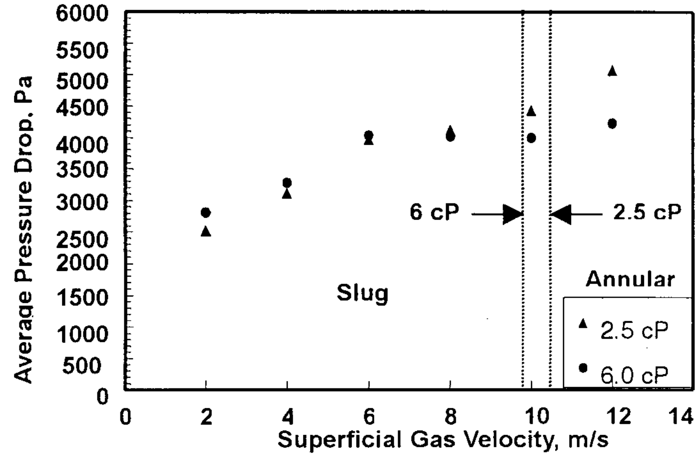


Figure 5. Comparison of the Average Pressure Drop
Vsl = 1.5 m/s, 0 ppm DRA, Horizontal Pipes

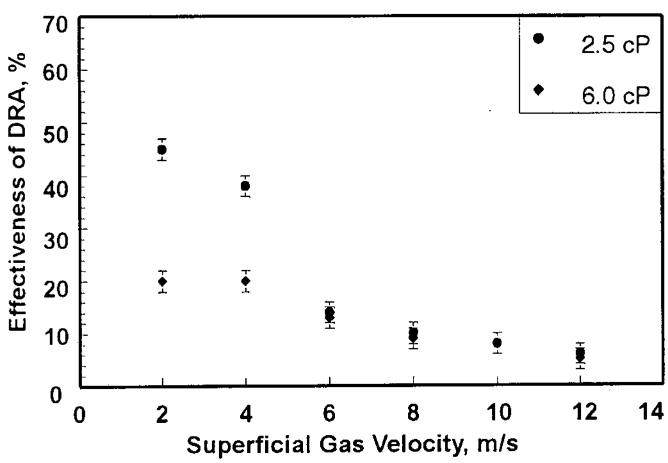


Figure 6. Comparison of Effectiveness of DRA
Vsl = 1.5 m/s, 20 ppm DRA, Horizontal Pipes

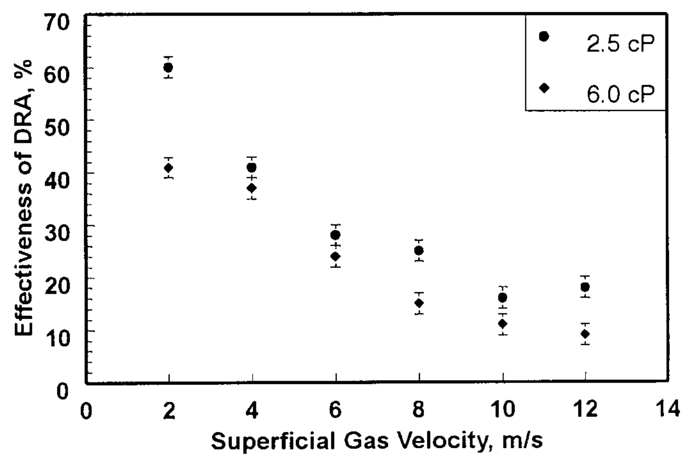


Figure 7. Comparison of Effectiveness of DRA
Vsl = 1.5 m/s, 50 ppm DRA, Horizontal Pipes

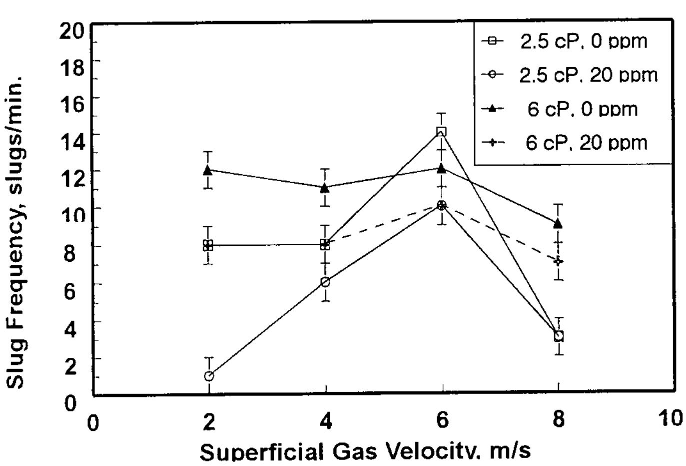


Figure 8. Comparison of Slug Frequency
0 and 20 ppm DRA, Vsl = 0.5 m/s, Horizontal Pipes

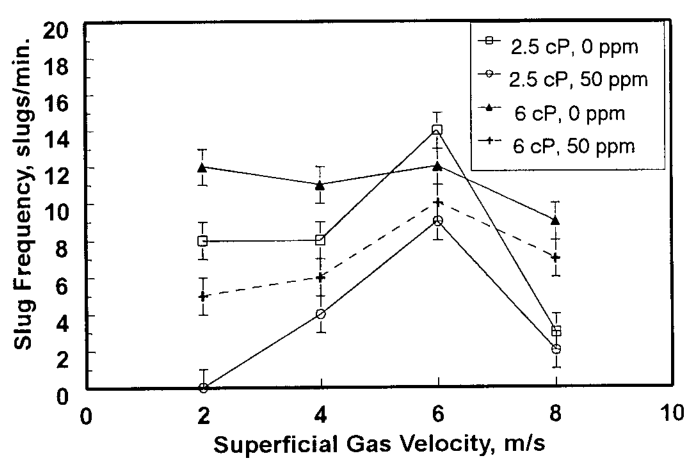


Figure 9. Comparison of Slug Frequency
0 and 50 ppm DRA, Vsl = 0.5 m/s, Horizontal Pipes

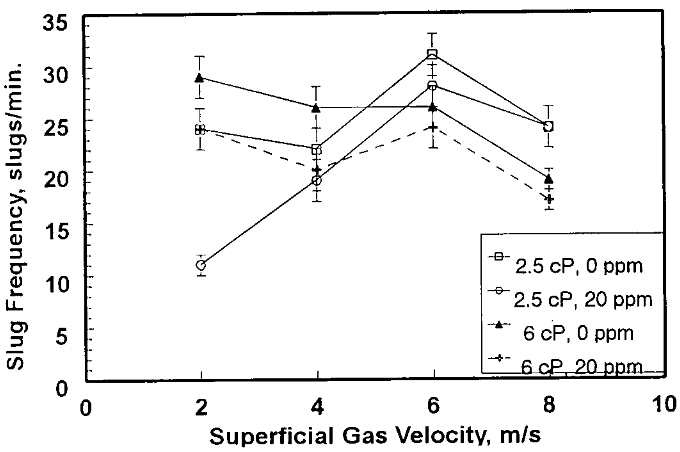


Figure 10. Comparison of Slug Frequency
0 and 20 ppm DRA, Vsl = 1.0 m/s, Horizontal Pipes

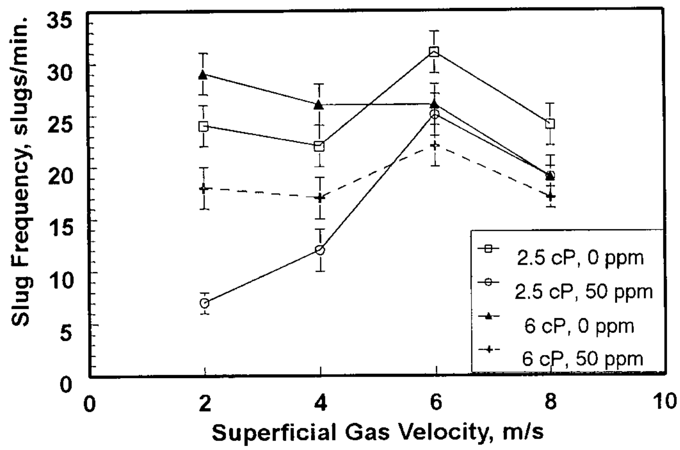


Figure 11. Comparison of Slug Frequency
0 and 50 ppm DRA, Vsl = 1.0 m/s, Horizontal Pipes