Investigations on Drag Reduction by Interactions between Polymer and Surfactant and Polymer and Polymer

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

A large amount of studies have been carried out on pipeline flow with several kinds of drag reducing agents, especially polymers and surfactants. Drag reducing agents, by definition, are additives which help suppress or eliminate turbulence in a pipeline. The mechanism and methodology of polymer only or surfactant only as drag reducing additives have been fully discovered. Whether mixed drag reducers such as polymer-surfactant or polymer-polymer systems would be effective is still not clear. In our study, polymer-surfactant and polymer-polymer mixed additives are used in order to explore the synergistic effects and interactions in pipeline flow loops.

The experimental work was divided into two sections: bench-scale experiments and pilot-scale experiments. In bench-scale experiments, the properties of prepared fluids such as, surface tension, conductivity and shear viscosity were measured. Several comparison methods and calculations were applied to give better understandings of the properties resulting from mixing of polymer with surfactant and polymer with polymer. After analysis of the properties, several combinations of concentrations were selected and solutions were prepared in the main tank of pilot plant and pumped into the pipeline set-up to test the pipeline flow behaviors. Turbulence structure/Reynolds number, pipe diameter, polymer-surfactant concentration were all considered as influencing factors. Critical micelle concentration, critical aggregation concentration, polymer saturation point, the onset of drag reduction, and the interactions between the mixed additives were discussed. A comparison between pipeline results and the predictions of Blasius Equation or Dodge-Metzner Equation were also discussed..

For polymer-surfactant studies, a commonly used polymer additive – carboxylmethylcellulose (referred to as CMC which is anionic) was selected as the drag reducing agent. The performance of this polymer was investigated in the presence of six surfactants respectively – Alcohol ethoxylate (referred to as Alfonic 1412-9 and Alfonic 1412-3 which are nonionic), Aromox DMC (nonionic surfactant), Stepanol WA-100 and Stepwet DF-95 (which mainly consist sodium lauryl sulfates, anionic surfactant) and Amphosol (which is zwitterionic).The experiments were first conducted with pure CMC solution with different concentrations (100ppm, 500ppm, 700ppm and 1000ppm) as a standard. The 500ppm CMC solution was selected as the best polymer concentration with highest drag reduction efficiency. For polymer-surfactant combinations, CMC-Alfonic 1412-9, CMC-Alfonic1412-3, CMC-Stepanol and CMC-Stepwet systems were found to have significant interactions. High surfactant concentration resulted in reduction in %DR. The addition of Aromox

increased the drag reduction ability and onset point when concentration was higher than the polymer saturation points. Also, both hydrophobic and electrostatic interactions were thought to have an effect on critical micelle concentration, which led to the fluctuations in the %DR.

For polymer-polymer studies, PAM-PEO system at two different polymer concentrations were investigated. Overall, Pure PAM solution had much higher drag reduction ability than pure PEO solutions. Mixing them together, strong interactions occurred when PEO fraction was high (over 50%) which affected %DR and shear viscosity substantially. Power-law constants n and k were also taken into account and found to exhibit opposite trends with the increase of PEO fraction.

Acknowledgements

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1.1 Introduction

1.1.1 Polymer Overview

Polymer, by definition, is a large molecule made up of rings and chains of linked monomer units. "Addition" and "condensation" polymerization occurs via a variety of mechanisms to process monomers molecules together, resulting in the formation of a single molecular with a high molecular weight [1]. Taking Polystyrene as an example, each styrene monomer's double bond reforms as a single bond plus a bond to another styrene monomer, this process repeat for several time and then polystyrene are formed[1] (**Figure 1**). Based on the derivation, they can be classified into 2 categories, natural polymers such as silk, wool, DNA, cellulose and synthetic polymers include nylon, polyethylene, Teflon, epoxy. This macromolecular science has had a significant impact on the way we live. It is very difficult to find an aspect which is not affected by polymers. Plastics, fibers and elastomers like rubber, are all common applications of polymers in our daily lives.

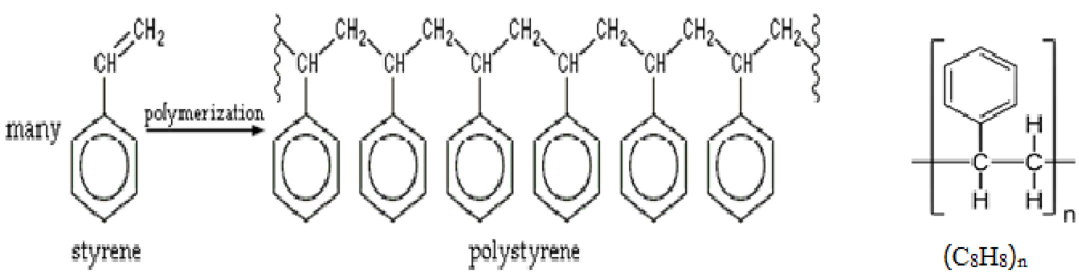


Figure 1 Formation of polystyrene

1.1.2 Surfactant Overview

Detergents, wetting agents, emulsifiers, foaming agents and dispersants are surfactants. They are compounds have surface-active property and lower the interfacial tension between two liquids or between a liquid and a solid. Usually, they contain both hydrophobic groups (tails) and hydrophilic groups (heads), which makes it possible to diffuse in water and adsorb at interface between air and water or at the surface between oil and water. Polar head group is a basis of classification, if there is no charge group in its head, it is non-ionic surfactant. An ionic surfactant carries a net charge head. If the charge is only one kind (positive or negative), it is specifically called anionic or cationic surfactant. If a surfactant contains a head with two oppositely charged groups, it is termed zwitterionic surfactant.

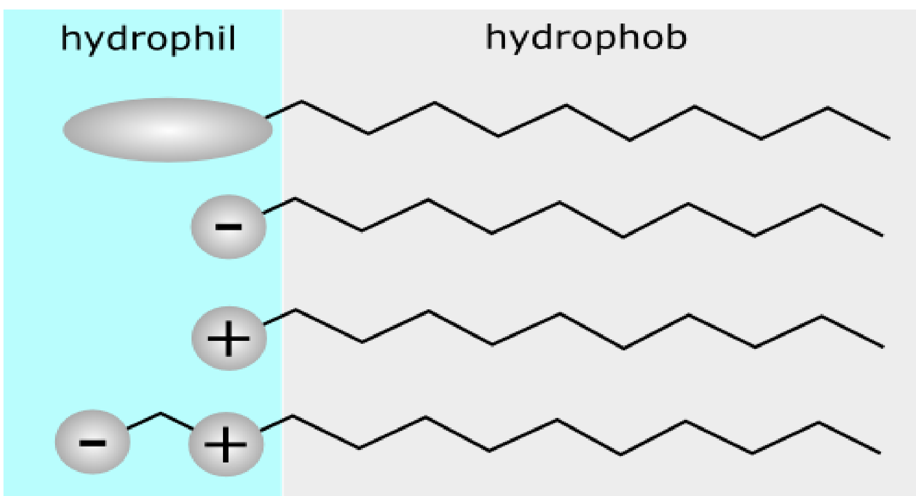


Figure 2 Surfactant classification according to the composition of their head: nonionic, anionic, cationic, zwitterionic.

1.1.3 Drag Reduction

The phenomena “drag reduction” was first discovered and reported by a British Chemist Tom in 1948, which received extensive attentions due to the suggestion of practical benefits, such as increasing pipeline transport efficiency, decreasing friction on the bottom of marine vessel and is also beneficial in wall turbulence and molecular rheology theoretically stimulating.[2]. It has been found that little amount of certain contaminants in water can contribute to a great decrease on turbulent friction on the surface where the fluid flows or bodies moving through the fluid [3]. Over sixty years' extensive research in this field, additives like polymers, surfactants and air bubbles are discovered to be some of those "contaminants" ,which is also termed as Drag Reduction Agents (DRA). By definition, DRA are any material or additive that reduce frictional pressure during fluid in a conduit or pipeline. Researchers and engineers also found DRA has a variety of benefits especially in industrial area. Firstly, it is possible to increase flow using the same amount of energy or decrease pressure drop for the same flow rate of fluid in pipelines. Then, as a prerequisite to maintain throughput, DRA can reduce transportation time and carbon emissions of pump stations. Moreover, avoiding consumption cost and total investment. Certain DRA can perform a drag-reducing ability up to 80% or increase flows rates by more than 100%.

DR has been applied to numerous applications currently in a large amount of field, for example oil pipelines, oil well operations, flood water disposal, firefighting, field irrigation, transport of suspension and slurries, water heating and cooling systems, airplane tank as well as marine systems [4]. Actually, as we know, drag reduction is not only limit in these aspects, it can also occur in some other fields created by humans spontaneously or in nature, where need to be further discovered in the future.

Despite so many discoveries and applications on DR, our understanding still has great limitations. More researches and experiments are required to fully clarify the value of DR on both empirical and theoretical perspectives.

1.2 Objectives

The specific objectives of this research are as follows,

1. To determine whether there occurs any interaction between polymers and surfactants;

   In order to test the interactions between polymers and surfactants, bench-scale experiments were conducted, properties such as surface tension, conductivity, shear viscosity and relative viscosity were measured and analyze. On the basis of relative literatures, the degree of interactions can be estimated.

2. To determine whether there exists a synergistic effect on drag reduction in transportation of polymer-surfactant or polymer-polymer solutions in pipelines;

   Pilot-scale experiments were carried out to test flow behaviors of polymer-surfactant solutions in pipelines. The collected data were compared with pure polymer solutions at the same conditions. The polymer selected in 1 and 2 is Carboxyl methyl cellulose (CMC). Non-ionic (Alfonic 1412-3, Alfonic 1412-9, Aromox), Anionic (Stepanol WA-100, Stepwet DF-95) and amphoteric (Amphosol) Surfactants were selected as surfactants.

3. To determine whether there the drag reduction effect is intensified effect by combining two good drag-reducing polymers together;

   PAM and PEO are both extensively researched polymers with excellent drag reducing ability. In our research we prepared PAM/PEO solutions at constant total polymer concentrations (500ppm and 1000ppm) and measured their bench-scale and pilot-scale properties. Power-law constants (n and k) were also taken into account.

4. To determine several influencing factors on drag reduction in different systems.

   A variety of combinations of polymer and surfactant concentrations were studied in every system. In order to test the pipeline diameter effect, two different diameter pipes, 1inch and 1.5inch pipes, were utilized. The effects of different surfactants on DR were also discussed.

1.3 Outline

This thesis consists of seven chapters including this introduction. In Chapter 2, general definitions and equations used in this study are presented. Chapter 3 covers the basic concept and mechanism of drag reduction as well as literature reviews on drag reduction by polymers and surfactants. Reagents used in our research, experimental techniques, set-up and procedures are discussed in Chapter 4.

Chapter 5 to 6 describe new experimental results .Chapter 5 explores polymer-surfactant systems consisting of polymer CMC and different kinds of surfactants. Chapter 6 describes polymer-polymer system consisting of PAM and PEO. The association between PAM and PEO is explored both at bench-scale and pilot-scale. A summary of the conclusions and recommendations is presented in Chapter 7.

Chapter 2
Background of Drag Reduction

2.1 Basic Definitions

The conservation of mass equation (Equation 2.1) is one of the governing equations in fluid transport phenomena field. If we introduce Newton's second law of motion and the friction between fluid elements, Equation 2.2 will be obtained.

$$\mathbf{0} = \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{V})$$ **Equation 2.1**

$$\rho \frac{\partial \vec{v}}{\partial t} + \rho \overrightarrow{V \cdot} \nabla \vec{V} = -\nabla P + \rho \vec{g} + \nabla \cdot \underline{\tau}$$ **Equation 2.2**

Where, $\boldsymbol{\rho}$ is fluid density, $\vec{V}$ is the velocity vector, $\boldsymbol{P}$ is pressure and $\underline{\boldsymbol{\tau}}$ is viscous shear tensor.

Taking "rheology" into our consideration is also important. It describes how matter deforms and flows, including elasticity, plasticity and viscosity. Whether a fluid is Newtonian and non-Newtonian can be distinguished by evaluating the relationship between viscous shear tensor and stress state and the rate of deformation tensor.

For Newtonian and Non-Newtonian fluid, different equations are required to describe viscous shear tensor. For Newtonian fluid, shear stress and shear rate have a linear relationship.

$$\boldsymbol{\tau} = \boldsymbol{\mu} \dot{\boldsymbol{\gamma}}$$ **Equation 2.3**

Where $\dot{\gamma}$ is referred as shear rate exerted on the fluid and μ is a constant, representing fluid shear viscosity.

As for non-Newtonian fluid, the relationship between shear stress and shear rate is non-linear, the shear stress and apparent viscosity can be determined by power law constants K and n.

$$\boldsymbol{\tau} = \boldsymbol{K} \dot{\boldsymbol{\gamma}}^{\boldsymbol{n}}$$ **Equation 2.4**

$$\boldsymbol{\eta} = \boldsymbol{K} \dot{\boldsymbol{\gamma}}^{\boldsymbol{n-1}}$$ **Equation 2.5**

Where the n and the K indicate the degree of non-Newtonian behavior and the viscosity level at a certain shear rate.

Non-Newtonian fluids also have three classifications, 1. Bingham-plastic fluids: a yield stress is required to initiate flow. 2. Dilatant fluids: if you increase shear rate, its apparent viscosity will go up as well. 3. Pseudoplastic fluids: apparent viscosity decreases with a rising in shear rate.

2.2 Flow Behaviors in Pipelines

First of all, there are two different types of flow, laminar and turbulent. When a fluid flows in parallel layers, in fluid dynamics, it is called laminar flow. The particles of fluid in laminar flow move orderly and there are no cross-current perpendicular to the direction of flow, nor eddies or swirls of fluids. High momentum diffusion and low momentum convection are characterizations laminar flow regime. While, turbulent flow regime is characterized by chaotic property changes, including low momentum diffusion, high momentum convection and rapid variation of pressure and flow velocity in space and time. Reynolds number is a very significant factor in determining laminar and turbulent flow. Normally, flow with a Reynolds number larger than 5000 is turbulent, while those with low Reynolds number are laminar. In a pipeline, depending on the viscosity and velocity of the fluid, both laminar and turbulent flow will occur. **Figure 3** shows the different structure of laminar flow and turbulent flow in pipelines. Both laminar flow and turbulent flow the shear stress can be described by the applied shearing force over the surface area to which the force is applied.

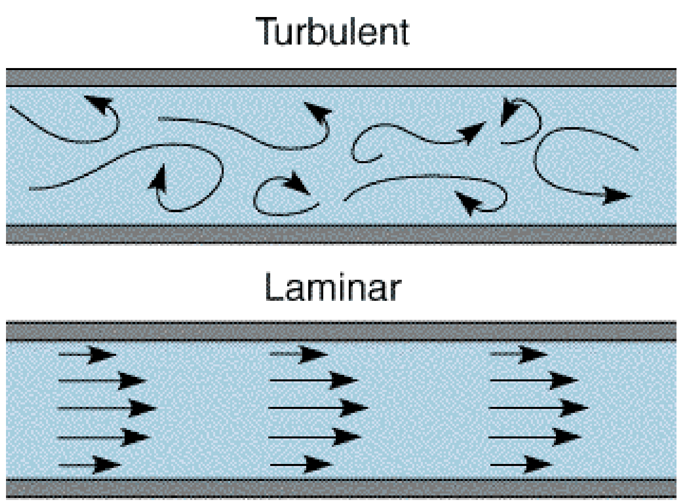


Figure 3 Different Structures between Laminar Flow and Turbulent Flow

In horizontal pipelines, fluid flow can be easily affected by pipeline boundary layers, thus the velocity will vary due to the growth of this boundary layer after fluid entrance (left side of **Figure 4**). When velocity profile is no longer change along the pipe, the fluid is said to be fully developed. Correspondingly, the friction factors, the main parameters we are going to measure are decreasing with the development of fluid and will remain stable when the fluid is fully developed. While there is an increase of friction in the transitory stage between laminar and turbulent flow regime. The length of pipeline to make flow to reach fully developed condition is called hydrodynamic entrance length (L_e), for laminar flow and turbulent flow, the hydrodynamic entrance lengths are different. Empirical relations are shown below.[5]

For laminar flow: $\frac{L_e}{D} = 0.06Re$ **Equation 2.6**

For turbulent flow: $\frac{L_e}{D} = 0.06Re^{1/6}$ **Equation 2.7**

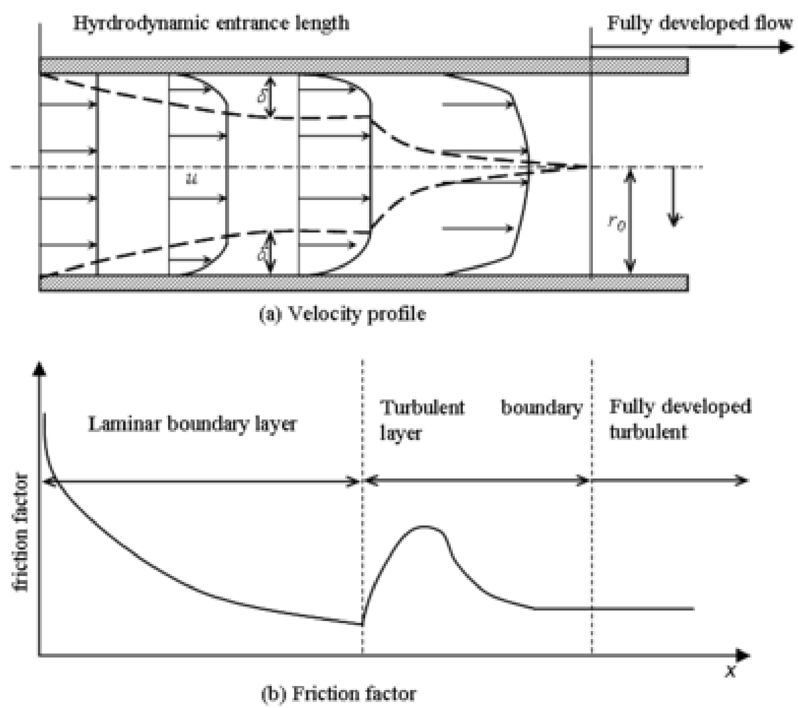


Figure 4 (a) Velocity profile in laminar flow (b) The relationship between friction factor and flow velocity [92]

The wall shear stress in a fully developed laminar flow of an incompressible Newtonian fluid in a horizontal pipe is given as:.

$$\tau_w = \frac{D\Delta P}{4L} = \mu \frac{8V}{D} \qquad \textbf{Equation 2.8}$$

Where τ_w is the wall shear stress, D is the pipeline diameter, ΔP is the pressure drop, L is the length of pipe and V is the average flow velocity

The pipeline pressure drop data are usually expressed in terms of friction factor and Reynolds number defined as:

$$f = \frac{\tau_w}{\frac{1}{2}\rho V^2} \qquad \textbf{Equation 2.9}$$

$$Re = \frac{DV\rho}{\eta} \qquad \textbf{Equation 2.10}$$

Where ρ is the fluid density,

If the fluid is non-Newtonian, power law constants K and n are introduced to give the following generalized forms

$$\tau_w = K\left(\frac{8V}{D}\right)^n \qquad \textbf{Equation 2.11}$$

$$Re_g = \frac{D^n V^{2-n} \rho}{\frac{K}{8}\left(\frac{6n+2}{n}\right)} \qquad \textbf{Equation 2.12}$$

$$f = \frac{16}{Re_g} \qquad \textbf{Equation 2.13}$$

The equations were developed by Metzner and Reed (1955), in order to discover a correlation of laminar friction in conjunction with a generalized Reynolds number defined to preserve the standard laminar relation in laminar regime. All of them depend on one prerequisite that is n does not change with shear stress.

As for fully developed turbulent flow transportation, it is barely calculated with an exact method. A turbulence model regarding to Navier-Stoke equations are applied with the aid of empirical knowledge to present the time averaged motion equation.

$$\rho\frac{\partial\overline{\vec{V}}}{\partial t}+\rho\overline{\vec{V}}\cdot\nabla\overline{\vec{V}}=-\nabla\overline{P}+\rho\overline{g}+\nabla\cdot\underline{\overline{\tau}}-\nabla\cdot(\rho\overline{\vec{v'}\vec{v'}})$$ **Equation 2.14**

In this equation, the overbars indicate those components are time-averaged. The term $\rho\overline{\vec{v'}\vec{v'}}$ could reflect the differences between laminar flow and turbulent flow, so it is referred to the Reynolds or turbulence stress. Prandtl's law (Prandtl-Karman) of friction could be derived by applying the Prandtl constitutive equation to this time-averaged motion equation in solving the turbulent problem.

$$\frac{1}{\sqrt{f}}=4.0log_{10}(Re\sqrt{f})-0.4$$ **Equation 2.15**

It is the most common representation of turbulent flow of Newtonian fluids and is appropriate over a large range of Reynolds numbers: $2100<Re<5\times10^6$, while one thing needs to be concerned that it is only an empirical equation based on several assumptions. Simple equations which have exact Re ranges have been experimentally concluded and all of them can be shown in the same form.

$$f=a+\frac{b}{Re^n}$$ **Equation 2.16**

Different parameters of equations suitable for this form with specific ranges of Reynolds numbers are shown in the following **Table 1**.

Table 1 Empirical equation coefficient for turbulent flow (Jhon, 2011)

EQUATION NAME	A	B	N	RE
BLASIUS	0	0.079	0.25	$4\times10^3<Re<10^5$
COLBURN	0	0.046	0.2	$10^5<Re<10^6$
KOO	0.0014	0.125	0.32	$4\times10^3<Re<3\times10^6$

A universally accepted equation for non-Newtonian fluid in turbulent flow was proposed by Dodge and Metzner (1959) by combing Prandtl-Karman law and power law together.

$$\frac{1}{\sqrt{f}}=\frac{4.0}{n^{0.75}}log_{10}\left(Re_G f^{1-\frac{n}{2}}\right)-\frac{0.4}{n^{1.2}}$$ **Equation 2.17**

Also, the relationship between fanning friction factor (f) and Reynolds number had been made a chart by Dodge and Metzner [6]themselves with both experimental regions and extrapolated regions to give a direct conclusion. (See Figure)

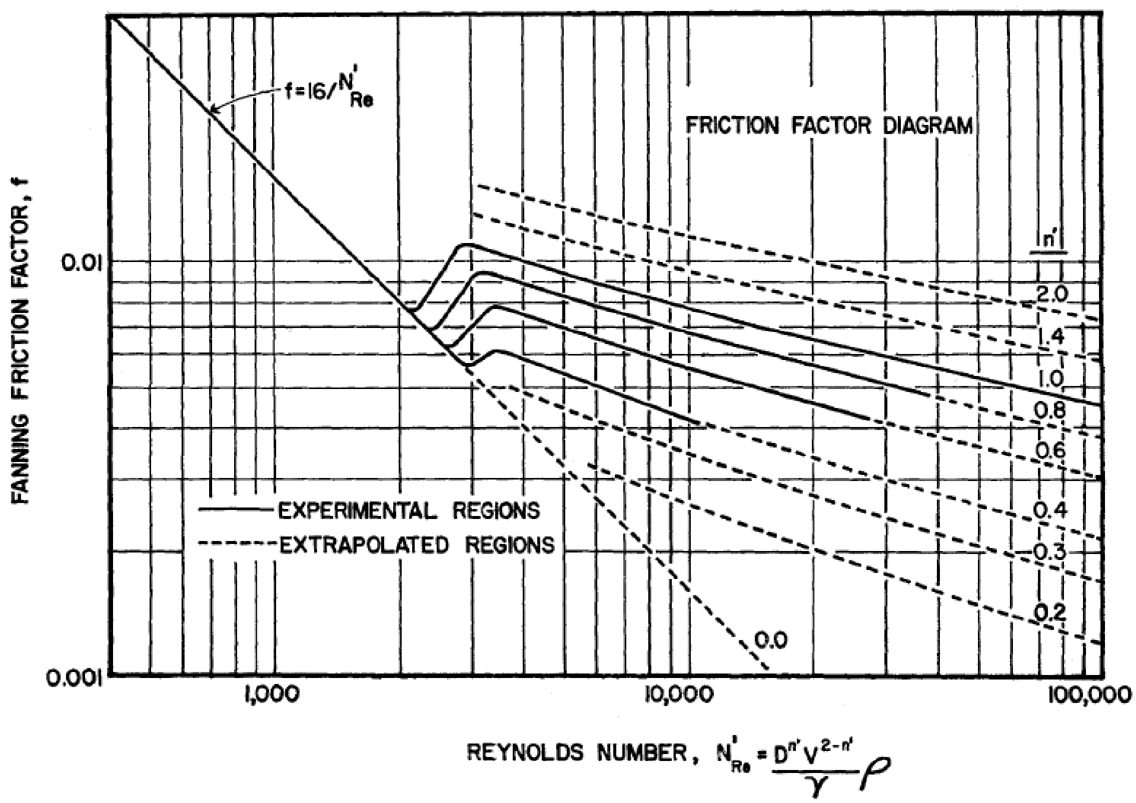


Figure 5 Final friction design for Newtonian and non-Newtonian fluids [6]

Besides the non-drag-reducing regime which is also term as Newtonian regime (shown from Equation 2.15 and Equation 2.17). There are also two regimes in fully developed pipe flow if any drag-reducing additives are added to the solutions.[7] A regime with drag reduction by the nature of additives, Virk supposed an approximate relation for this regime, that is

$$\frac{1}{\sqrt{f}} = (4.0 + \delta)log_{10}\left(Re\sqrt{f}\right) - 0.4 - \delta log_{10}\sqrt{2}dW^{*}$$ **Equation 3.2**

Where δ and $W^*$are solution parameters.

Another regime is an asymptotic regime of maximum possible drag reduction in which the friction factor is insensitive to the additive applied, which will be further discussed in the next chapter.

Totally, four kinds of flow regimes are exist in pipeline flow. They are Laminar, Newtonian, polymeric and maximum drag reduction regime. The characteristic of every regime and the transition field were discussed and discovered by Virk in 1975 by both experimental and theoretical explanations [7]. He also summarized several researchers' conclusions and separated the fluids in pipeline into three viscous sublayers.

DR can occur in both laminar and turbulent flow, while considering the practical conditions, its occurrence in turbulent flow is of great interest. More complex turbulent data had shown the addition of little amount of polymers and surfactants could have appreciable reductions in pressure drop. The next chapter will further discuss the previous data about non-Newtonian flow behavior in pipelines, especially drag-reducing ability.

Chapter 3
Literature Review

3.1 Drag Reduction Concept

The frictional loss in turbulent flow by adding a little amount of certain additives in pipes is termed as "Tom's Effect" or "Drag Reduction Effect" since it was first discovered and reported by Tom in 1948. A brief description of DR has been given by Gyr and Bewersdorff [8] and a large extent of experiments have been carried out in recent decades in order to provide a clear mechanism of DR and also explore more various systems.
The definition of DR is,

$$\%\boldsymbol{DR} = \frac{\boldsymbol{f_0 - f}}{\boldsymbol{f_0}} \times \mathbf{100}\% \qquad \textbf{Equation 3.1}$$

Where %DR is drag reduction percentage and f and f_0 demonstrate the friction factors of the tested solution and the solvent (Water in our experiments) respectively.
Polymers, surfactants, fibers and biological additives, air bubble [9] et al. are all drag-reducing additives which can produce drag reduction in many ways. Based on several researchers' results, our research only focus on polymer, surfactant and their combinations in the application of DR.
Although numerous researches and experiments have been put into this field, our understanding of drag reduction is still limit.

3.1.1 Maximum Drag Reduction Asymptote

Virk[7][10], supposed one maximum drag reduction asymptote and it is believed to be valid. The similar laws for the prediction of boundary-layer skin friction can be applied to estimate the maximum drag reduction[11]. The correlation is given by,

$$\frac{\mathbf{1}}{\sqrt{\boldsymbol{f}}} = \mathbf{19}\boldsymbol{log_{10}}\left(\boldsymbol{Re}\sqrt{\boldsymbol{f}}\right) - \mathbf{32.4} \qquad \textbf{Equation 3.2}$$

Or

$$f = 0.58Re^{-0.58} \quad \text{Equation 3.3}$$

This definition presents the maximum drag reduction ability achievable by polymer additives. In 1993, Zakin proposed a new asymptote for surfactant additives which has significantly lower asymptote values.

$$f = 0.32Re^{-0.55} \quad \text{Equation 3.4}$$

3.1.2 Mean velocity profiles

The turbulent flow velocity for Newtonian fluids in pipeline can be divided into three regions, they are

The viscous sublayer

$$U^{+} = y^{+}(0 < y^{+} < 5) \quad \text{Equation 3.5}$$

The buffer layer

$$U^{+} = 5.0lny^{+} - 3.05(5 < y^{+} < 30) \quad \text{Equation 3.6}$$

The turbulent core

$$U^{+} = \frac{1}{k}lny^{+} + C^{+}(y^{+} > 30) \quad \text{Equation 3.7}$$

While as for smooth pipes,

$$U^{+} = 2.5lny^{+} + 5.5 \quad \text{Equation 3.8}$$

Where U^{+} is the local mean velocity, y^{+} is the distance from the wall.

After onset, for a given dilute polymer solution, a slope increment in velocity profile will occur due to the three-halves power of the number of backbone chain links per macromolecule which is dependent on skeletal structure. An ultimate profile was proposed by Virk when the maximum drag reduction occurs,

$$U^{+} = 11.7lny^{+} - 17.0 \quad \text{Equation 3.9}$$

3.2 Drag Reduction Mechanism

Generally, different researchers have a variety of opinions on DR and numerous experiments and stimulations have been done on this field over several decades.

Virk (1975) [7]believed the polymer-turbulence interaction is responsible for DR. An involvement of the macromolecule will commence around the peak turbulence energy production during the turbulent bursting process, which is the main factor to produce DR. By analyzing the onset of drag reduction, it was further confirmed macromolecular extension is related to the mechanism of drag reduction. He also left a suggestion that in order to maintain the overall cross-sectional turbulent energy balance, an increase in maximum kinetic energy of the inner flow might play a vital role in DR[12].

Brostow [13] created a model(see **Figure 6**)in 1983, it describes polymer chains attack solvent molecules simultaneously with the aid of eddies of the turbulence. For protective purpose, macromolecular chains will attach solvent molecules inside the domain. So, the larger pervaded volume by polymer chain, the higher drag reduction, but the entanglements of the polymer chains are not decisive. In this Figure, d is average distance between chain sequences on the outside of the domain oriented along the flow; dg and dp are average widths of good and poor sequences in obvious notation. Some researcher also believed DR is caused by the rheology nature of polymer solutions[14].

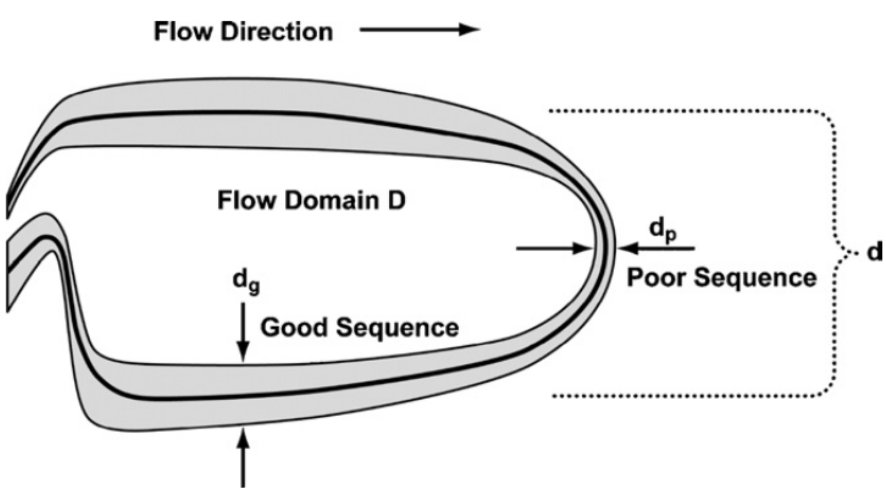


Figure 6 Mechanism of drag reduction (From Brostow[4]**)**

Small amount of dissolved polymer in the near-wall region and the influence of fluid injection into the near-wall region were studied as well [15]. Minute amounts of polymers removed from the polymer thread and dissolved in the bulk of the fluid would contribute to heterogeneous drag reduction. In this experiment, the results manifested more polymer injection points and polymer molecules removes from thread could have a better DR ability, while water injection is insane. At the same year, Bewersdorff and Thiel[16] elucidated that the pipe geometry, the Reynolds number and the additive concentration all affect the achievable drag reduction significantly. By analyzing the slopes of the velocity profile, it is found the hydrodynamic influence of the roughness is only restrict to the near-wall region. While as for surfactant solutions which has a less than 12 dimensionless roughness height in viscous unit, no influence was discovered on the turbulence. Besides, dilute polymer solution performed a higher DR ability in a smooth pipe, and with the increase of pipeline roughness, the maximum attainable drag reduction decline gradually.

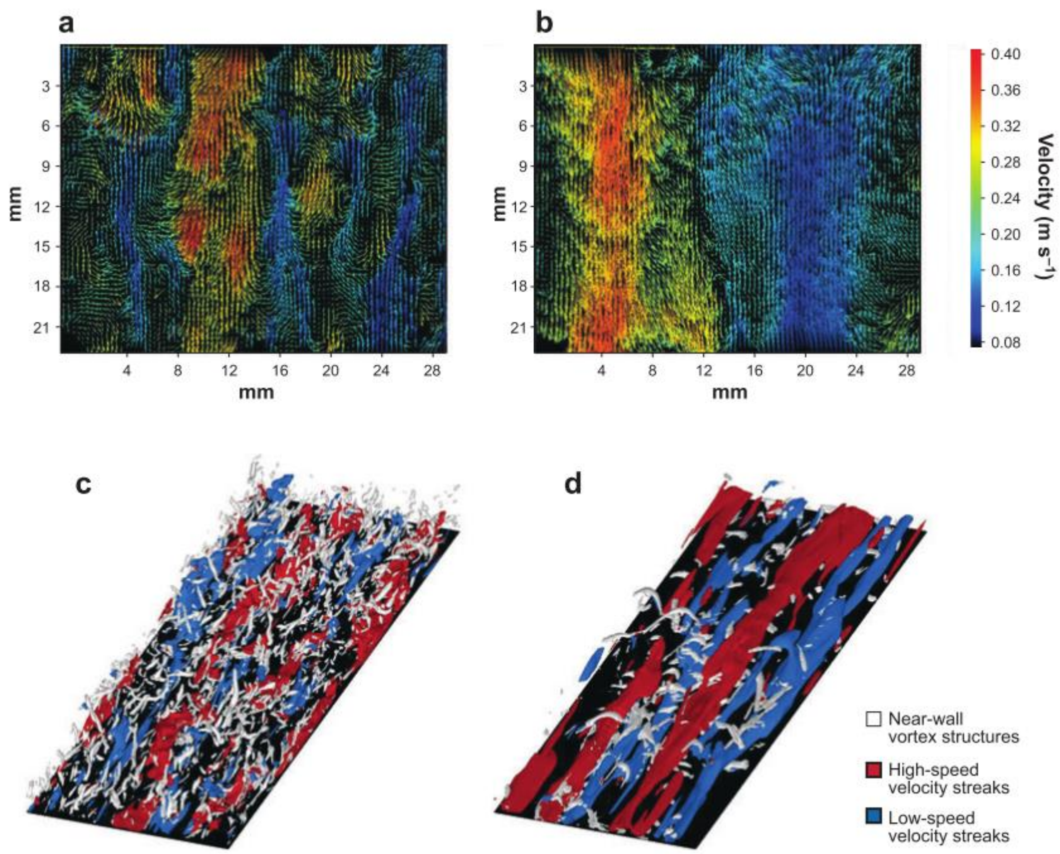


Figure 7 Streamwise and spanwise fluctuating velocity field (a&b) and near-wall vortex structure(from White&Mungal 2008 [17]**)**

According to the verdict of White and Mungal[17], they hold an opinion that small quantities of additives will have a profound effect on turbulent boundary layers. From **Figure 7**, the modification of near-wall structure in the turbulent boundary layers and the mean velocity profile decrease the wall friction significantly, which means the complexity of near-wall turbulence dynamics coupled with dilute polymer solution dynamics constitute the mechanism of polymer drag reduction. **Figure7** a and b shows particle-image-velocimetry vector plots of the streamwise and spanwise (from top to bottom) fluctuating velocity field at $y^+ \approx 20$ in (a) water and drag reduction of (b)≈60%. The following two figure c and d are instantaneous visualizations of near-wall vortex structures (from bottom to top) identified using isosurfaces of the positive second invariant of the velocity gradient tensor, high-speed velocity streaks, and low-speed velocity streaks for (c) Newtonian fluid and drag reduction of (d)60%. Totally, the assumptive mechanism is spatial polymer stress around the vortex can contribute to vortex suppression, thus reducing the turbulent friction drag.

Besides, several relative investigations also produced a large amount of theories and conclusions in the mechanism of DR. Hunston [18] and Tooner [19]conducted a series of experiments and proposed the viscous anisotropic stresses has a significant role in mechanism of DR by polymers. Benzi [20] compared the properties of rodlike and flexible polymers differences and gave some predictions in mechanism of DR. Researches of connection between the coherent structures in turbulent flows and polymer confirmation which can lead to DR were conducted by Kim [21] via dynamical simulations which track the evolution of hairpin vortices.

However, due to the limitation of current measurement techniques and our understanding in DR, an exact mechanism can’t be obtained. While, with continuous efforts and works on this field, the gaps between the truth and our knowledge will be reduced without a doubt.

3.3 Drag Reduction by Polymers (polymer, copolymer, polymer-polymer)

After reporting by Toms in 1948, DR has been widely investigated over 60 years. He also summarized his early experiments results in DR (up to 50% as compared to pure solvent when using a 0.25% by weight of polymethacrylate solution) and reported the relation between pressure head and rate of flow for a single solution[22]in 1977, which is regarded as a milestone in DR field. Meanwhile, molecular weight distribution was found to be very meaningful in understanding the behavior of mixtures by Lumley [23], he concluded that the fluctuating strain rate is responsible for molecular expansion in high wall shear stress regime and the expanded large eddies could produce an increased streamwise fluctuating velocity which is thought to be the postulated mechanism. Many investigations such as calculations on molecular expansion, measurements using monodisper samples of polymer, turbulence and mean profile measurements in flows in the maximum drag reduction regime and prediction of large eddy size can be suggested by this dynamical mechanism as well.

According to Shenoy's review [24], a diversity of drag reducing polymers were studied, such as guar gum, poly(ethylene oxide), poly(acrylamide), sodium carboxymethyl cellulose, poly(isobutylene) hydroxyethethylcellulose, polystyrene, polyphosphate and certain rubbers etc. Some of them even have an ability to produce DR ability which reach 80% in ideal conditions.

Turbulent drag reduction induced by both water-soluble poly(ethylene oxide) (PEO) and oil soluble polyisobutylene (PIB) was investigated by Choi and scaling functions of polymer-induce turbulent were proposed in polymer-solvent interaction [25], [26]. By comparing PEO and PIB in different conditions of flow, he found the intrinsic drag reduction of a drag-reducing polymer is uniform, regardless of the types of flow geometry and solvent, also higher molecular weights polymers show a maximum drag reduction at low concentrations.

The power-law model and its extended model in non-Newtonian fluid was used by Kim[10] in his thesis to further investigate the flow behavior of CMC polymer solutions in pipes.

Bonn[27] opened a way to a microscopic understanding of the enormous elongational viscosity in polymer solutions by addition of the biopolymer DNA molecules in 2005. Kalelkar [28] produced DR in a decaying turbulence condition and exhibited potential-energy spectrum of the polymer, hitherto unobserved features in the temporal evolution of the kinetic-energy spectrum and characterize intermittency from a new perspective.

Moreover, techniques like particle image velocity (PIV) and laser Droppler velocimetry (LDV) was utilized in determining the turbulent flow. The results from Zadrazil shows the appearance of DR is always accompanied by “shear layers” in polymer solutions. The mean thickness of shear layer region of polymer solution is responsible for the DR ability[29]. Warholic [30]also applied this method into his research under condition of 41% and 55% drag reduction solutions to study drag-reducing polymer on the structure of turbulence.

The major drawback of DR by one unique polymer is that the drag reducing polymers degrade very fast, as a result their DR ability is impaired. Several researchers reported extensive studies on polymer-polymer and polymer-fiber mixtures or copolymers to give a better solution to this problem. And meanwhile, some of these combinations may have higher DR abilities than that of either of the constituent polymers.

One of the pioneers Singh [31] observed polymer-polymer and polymer-fiber in recirculatory water flow set-up in 1985. Guar Gum, Xanthan Gum, Polyacrylamide, Carboxl methyl cellulose and Asbestos fibers were reagents used in the experiments. He concluded that the random colloid size of polymer molecule and rigidity of the polymer-fiber was believed to be the main factor contributed to synergism which did cause shear stability in DR flows. Deshmukh and Singh [32] preapared graft copolymers of xanthangum and polyacrylamide by ceric-ion-initiated solution polymerization technique. After testing its ability on DR, the results showed it promoted the DR effectiveness and biodegradation resistance significantly in contrast to xanthangum alone.

Malhotra [33][34]conducted extensive researches on polymer-polymer mixtures and found both DR ability and synergism are functions of concentration and flow rate. Besides, the shear stability of less shear stable drag reducer decreased drastically when there was a huge distinction between the incorporation of the polymers in shear stabilities.

More recently, Ma et al.[35]examined the drag-reducing properties of synthetic poly(dodecyl methacrylate)s by polymerization in kerosene solutions. The rise of both the molecular weight of the polymeric additive and the Reynolds number would extend the DR.

3.4 Drag Reduction by Surfactants

Generally, surfactants consist of one hydrophilic head group which is ionizable polar group and is able to form hydrogen bonds and one hydrophobic tail group which is a long chain alkyl group. In aqueous solutions, hydrophobic groups will aggregate together to avoid contact with water and hydrophilic group will surrounded with them for protection. This self-assembling system produced by surfactant will form micelles, which plays a vital role in DR by addition of surfactants. By classification, there are several micelle shape can be formed in aqueous solutions, such as globular/spherical, disk-like, cylinder or rod/worm/thread-like, bilayer spherical, hexagonal, lamella and cubic crystal. Every two shapes can transform from one to another when the properties of solution changed. By classification, there are four kinds of surfactants, anionic, cationic, non-ionic and zwitterionic, all of them have the ability to produce significant DR.

3.4.1 Anionic Surfactant

The first reference related to drag-reducing surfactant was reported by Savins[36]. A solution containing 0.2% sodium oleate with 10% potassium chloride could produce a maximum 82% DR in water. He found DR was kept rising with the increase of flow rate in turbulent flow until a critical shear stress was reached.

Pilpel [37] also did some experiments about aqueous soap solution, After viscoelasticity examinations, he discovered both the salts and the alcohols contributed to the transformation of spherical micelles into cylindrical structures, which is essential factor for DR effect.

By analyzing viscoelastic and some colloid chemical properties, Tsujii et al.[38] gave a point that partically neutralized alkenylsuccinates with a high viscoelasticity might be possible candidates for DR[39]. Also, after measuring a compounded additives of anionic surfactant and zwitterionic surfactants in water, most micellar solution phases of these mixtures were viscoelastic[40]. Tiddy[41] utilized optical microscopy and low angle X-ray scattering to determine phase structure and rheological properties of a mixed anionic/zwitterionic surfactant system and found some aqueous solutions were viscoelastic.

The negative charges of anionic surfactant interact with positive charges in tap water (Ca^{2+} or other cations) easily, which may reduce its DR ability to some extent. More researches and discussions are required to be made in the future because they are stable and inexpensive, which make them good candidates as drag reducer.

3.4.2 Cationic Surfactant

Bewersdoff and his colleage Ohlendorf [42] tested two rod-like micelle system containing CTAB with NaSal in turbulent flows in pipe of different diameters. They found surfactant solutions presents characteristic flow regimes, which can be affected by excess salt, surfactant concentration or temperature. Cai et al.[43]further discovered the mechanism of turbulent frictional drag reduction by CTAB on the first step relaxation time.

Generally, Habon G is regarded as cationic surfactant and has been reported by Hetsroni et al. [44] about its DR ability and heat transfer in both adiabatic and diabatic flows (fully developed laminar pipe flows). The results showed Habon G is a good drag-reducing agent which can produce 50% DR ability approximately and has a higher heat transfer coefficients than that in water.

After extensive researches, Qi and Zakin [45] observed the effectiveness of cationic surfactant DR ability depends on counter-ion structure effect and the chemical structure of surfactant. Besides, shear-induced structure (SIS) and viscoelasticity are not as significant as extensional viscosity for surfactant drag reduction.

CTAC is a welcomed cationic surfactant as a drag-reducing agent which has an ability to produce significant DR in channel. Gu and Wang [46] utilized PIV measurements in their experiments to measure two-dimensional velocity fields of the channel flow and concluded the onset and offset point of DR by using CTAC solutions. They found “Zero Reynolds shear stress” in surfactant drag reduction results from wall normal fluctuations and its symmetrical distribution in quadrants. Li et al.[47]has done some discoveries upon CTAC solutions. By structural analysis, surfactants did have some effects on fluid movement from the wall and toward the wall, but no effects were found in interactions of fluid. Wall-normal turbulent heat flux was also tested. A combination of CTAC with addition of NaSal had the same DR effectiveness regardless of concentration. A rise of temperature and the use of tap water exhibited higher DR ability[48].Other cationic surfactant like Ethoquad 0/12[49] and one surfactant containing oleylbishydroxyethyl methyl ammonium chloride[50] also have been investigated.

Cationic surfactant has been used and discovered extensively both in laboratory level and industrial level since they have no interactions with ions in tap water which is regarded as a remarkable advantage. While it is expensive compared with other surfactants.

3.4.3 Non-ionic Surfactant

Non-ionic surfactant in DR was first reported by Zakin and Chiang in 1972[93]. Solutions of Alfonic 1214-60 in distilled water with varying amounts of $NaSO_4$ were prepared and tested. The onset and maximum ability of DR of non-ionic surfactant was presented.Another non-ionic surfactant Alfonic 1412-7 solution was tested in different diameters of pipes by Kim[10] in his thesis, 0.525M and 0.575M $MgSO_4$ were added as a salt. Noticeable drag reduction has been discovered at a very low surfactant concentration at high flow velocities in turbulent regime.

Xia et al.[51] conducted a comparison between 100ppm Sodium Dodecyl Sulphate (SDS, anionic surfactant) and 300ppm Alkyl Polyglycoside (APG1214, non-ionic surfactant) with the increase of temperature about DR ability and found APG is a better drag-reducing agent than SDS.

Aromox which mainly consists of oleyldimethylamineoxide is also an excellent drag-reducing agent with Reynolds number ranging from 1000 to 60000 in pipe flow[52]. The maximum DR ratio was found to be 50% in the boundary layer flow and larger than 60% in pipe flow. Turbulence statistics and turbulence structure were also discussed. Recently, Tamano et al.[53] focused on the comparison of turbulence statistics between heterogeneous solutions (by injection) and homogeneous solutions (by premix). Noticeable differences were found in streamwise and wall-normal turbulence intensities, while both cases had the same maximum drag reduction ratio at the most downstream position (50% approximately).

A series of experiments about non-ionic surfactants on DR have been done by Cho et al.[54]. He tested SAOB, SAOBSS, SAOBGA, PSAOB-1, PSAOB-2 and SASOR in a close loop and obtained valuable conclusions. The conditions (concentration, temperature, salt ratio) of maximum DR performance of every surfactant were discovered and a comparison was also conducted in their experiments.

Friction factor of transporting oil –water emulsions could be reduced by surfactant as well. Omer and Pal[55] prepared emulsions with EDM-244 oil with addition of Emsorb 2503 in pipelines and analyzed the effect of surfactant concentration, water concentration and droplet size of emulsions on pipeline flow behaviors.

Comparing with other types of surfactants, non-ionic surfactants will not interact with ions in solutions (for example Ca^{2+} in tap water), so it has extensive uses. Moreover, they are both mechanically and chemically stable, biodegradable ability and low toxicity make it less polluted when a leak occurs within district cooling system.

3.4.4 Zwitterionic Surfactant

Zwitterionic surfactants have both positive and negative charges on their head group, which makes them very sensitive to the ions presented in solvents.

In 2001, Myska et al. chose SPE 98330 as drag reducing agent in hydraulic loop. After extensive researches, the highest effectiveness of DR was found at lower additive concentration with lower viscosities. Besides, both higher temperature and unsoftened tap water (without Trilon A) will produce higher DR effectiveness.[48] At the same year, Stern[56] also gave a brief description upon SPE 98330 as a drag-reducing agent, the influence of solvent quality on both the viscosity and elasticity of surfactants, differences in the storage modulus and shear induce state were investigated and detected.

A newly synthesized zwitterionic surfactant named oleyl trimethylaminimide has been researched by Wei et al.[57]in a channel. Both drag and heat transfer reduction characteristics were found during the experiments. Surprisingly, a 83% maximum drag reduction could be reached at 25℃ when surfactant concentration was 200ppm.

Chapman[58] has done a series of experiments related to the drag reduction ability of zwitterionic surfactants which were chosen due to their quick self-reassembly ability after being degraded by mechanical stress in order to find environmentally benign surfactants with equal drag reduction ability with that of cationic surfactant. Oleyl trimethylaminimide, DR0206, SPE 98300, Chemoxide OL, Oleyl Betaine and Oleyl (chem) Betaine were all his tested surfactans. Beside, different solvents such as pure water, 20%Ethylene Glycol/Water, 30% Glycerol/Water, 25% Profpylene Glycol/Water were also discussed in his reports.

3.5 Interactions between Polymers and Surfactants

Both polymer and surfactant are effective drag-reducing agents and have been discovered and researched over several decades in a variety of fields such as drug delivery, oil recovery and even cosmetics industry. Only a few articles focus on the synergistic effects of polymer and surfactant together on pipeline flow behaviors.

As described before, surfactant starts to assemble at critical micelle concentration (CMC). The mixing of water soluble polymer, surfactant monomers and salt in water, forms aggregates structure due to the interactions between polymers and surfactants which will affect the solution rheology drastically. The aggregate is formed at a well-known concentration called critical aggregation concentration (CAC) and is influenced by the nature of surfactant head group, the presence of polar groups on the polymer backbones, the level of polymer hydrophobicity and polymer flexibility[59]. In contrast to the components alone, the aggregates formed by interactions degrade much slower and could exhibit valuable DR in a relative larger range of Reynolds numbers. Usually, the CAC is found to be lower than CAM in polymer-surfactant systems. Goddard [60] concluded that polymer-surfactant interactions can be divided into categories, 1) ionic polymers with opposite charged ionic surfactant, for this category, CAC can be several orders lower than CMC; 2) neutral polymer with ionic surfactant, where CAC is slightly lower than CMC. Though ionic polymer with non-ionic surfactant system is less common, it can be included in the second category because the CAC is comparable to CMC in this system. In general, polymer and surfactant can interact in two methods, Electrostatic interactions (polymers and surfactant have opposite charges) and hydrophobic interactions (between the hydrophobic parts of polymer and surfactant).

Nagarajan[61] suggested one thermodynamic model to predict the mechanism of surfactant binding onto polymers in aqueous solutions. The intramolecular contacts between hydrophobic and polar head of polymer will form a medium interface where is a preferential location for surfactant binding. Several relative theoretical articles also focused on this field which make polymer-surfactant systems developed on a large extent. One year later, on the basis of Nagarajan's theory, another model was proposed by Ruckenstein et al.[62]according to the adsorption on micelle surface. The surface free energy between micellar hydrocarbon core and the solvent inside of the coiled macromolecules will change, which contributes to higher interaction intensity.

When the surfactant concentration reaches one point known as polymer saturation point (PSP), polymer molecules are saturated with the little amount of surfactant. An additional surfactant concentration will result in the formation of free micelles and the reduction of surface tension till a constant level.

Figure 8 illustrates a comparison between CMC, CAC and PSP points on surface tension at a fixed polymer concentration. Clearly, according to the surfactant concentration on the horizontal axis, PSP>CMC>CAC. In most systems with weak interactions between polymers and surfactant, CAC and PSP are the same as CMC in pure surfactant solutions

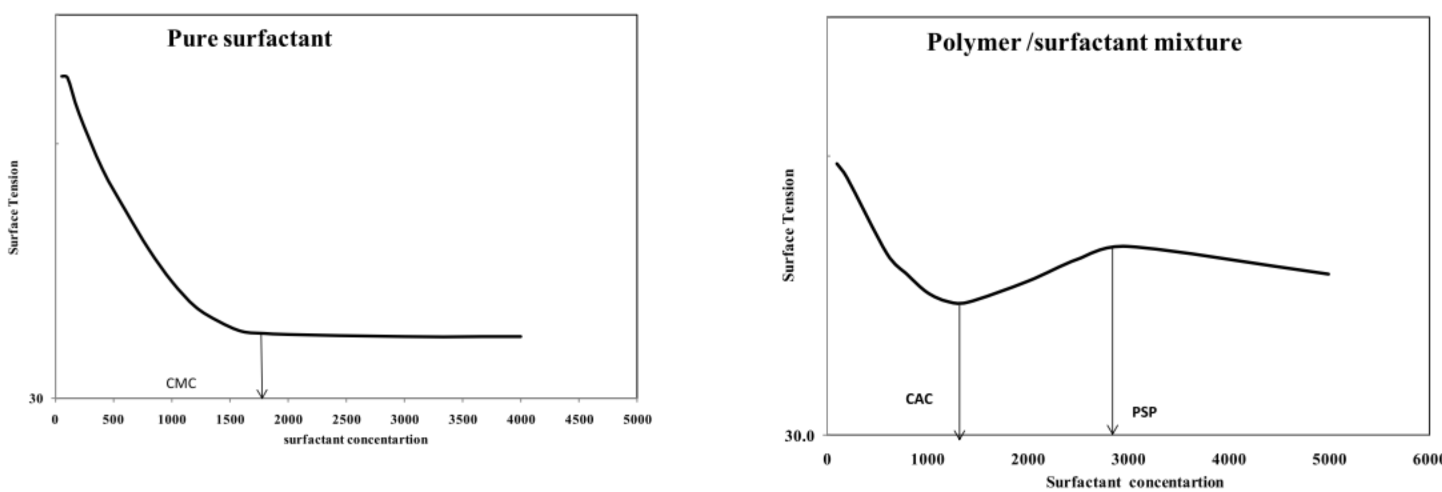


Figure 8 Qualitatively plots of surface tension for pure surfactant solution and surfactant mixed with polymer solution(From Mohsenipour,2011[5]**)**

3.5.1 Interactions between Non-ionic Polymers with Surfactants

When ionic surfactant is introduced to non-ionic polymer solutions, interactions will occur to form micelle-polymer associations. Nagarajan[63] suggested “necklace model” to explain the aggregations between non-ionic polymer and surfactant micelles. Polymer segments penetrated into the polar head group of micelles and protected hydrophobic tails from contacting water.

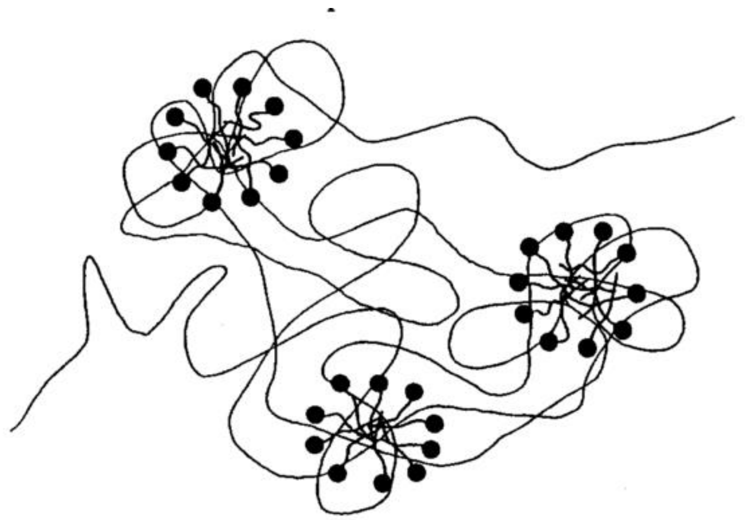


Figure 9 Schematic representation of the polymer-micelle association structure

Hydrophobicity also has been reported by several researchers about its importance on the interactions of polymer-surfactant systems. Typically, polymers with more hydrophobic tails presented better interactions with surfactants[64]. Thuresson et al.[65]determined the effect of hydrophobic modification of selected polymers in a SDS-ethyl(hydroxyethyl)cellulose system using NMR, ion-selective electrode and a time-resolve fluorescence techniques and observed that the hydrophobic groups of the polymer have a significant effect on the surfactant binding process at very low surfactant concentration. If increasing the content of surfactant, this influence goes down gradually with mixed micelles formed. By comparing the interactions of hydrophilic and amphiphilic polyesectrolytes with surfactants specifically, Anthony and Zana [66], [67] concluded that polyelectrolyte hydrophobicity plays a domain role in determining the intensity of interactions.

Jones[68], acting as a pioneer in non-ionic polymer with surfactant interactions, a system containing PEO and an anionic surfactant SDS was tested in 1967. After that, Patterson and Little[69] applied PEO with several anionic surfactant solutions into DR measurements. Though little depression was discovered at very low soap concentrations, substantial DR (up to 75%) was produced in the stronger soap solutions which suggested that polar groups of surfactant interacted with non-ionic polymer and good drag-reducing micelles formed. In the beginning, the binding of surfactant onto polymers impaired the amount of hydrophobic chains resulting in the shrinkage of polymer coil, this might be the reason of initial dip in %DR. As the surfactant concentration increased, polymer chains elongated to reach a higher DR.

One cationic surfactant (OTAC) and one anionic surfactant (SDS) were selected by Mohsenipour and Pal [70], [71] to examine their DR performance in pipelines. In contrast to pure polymer and surfactant solutions, considerable synthetic effects were observed in both systems. Interactions between polymer and surfactant were discussed by analyzing surface tension, conductivity and relative visocosites.

A combination of non-ionic polymer PEO with cationic surfactant CTAB has been fully detected by Matras and Malcher et al.[72]–[74] with their constant researches from 2008 to 2015. In their experiments, simultaneous addition of polymer and surfactant with assistance of NaSal exhibited much stronger DR ability than each substance alone and the self-rebuilding mechanism in polymer-micellar system gave this system a better degradation resistance ability at optimum conditions. Considering flow behaviors, when Reynolds number was high, two critical points were observed where micelles lose their orientation firstly and then the disintegration of aggregates got to start. Both of them would lead to abrupt increases in friction factors and dynamic viscosity. Recently, the domain factors in stable transitional zone, unstable transitional zone and turbulent drag reduction zone were discussed as well.

Suksamranchit et al.[75][76]proposed a new question about whether aggregates in polymer-surfactant system will have an influence on turbulent wall shear stress. They utilized one system containing PEO (non-ionic polymer) and HTAC (cationic surfactant) in Couette flow and found interactions could occur at low surfactant concentration due to the stretching of polymer chains under high shear stress. The addition of surfactant in low molecular weight polymer solutions could produce similar DR with no surfactant additive in high molecular weight polymer solutions. Also, it is believed turbulent wall shear stress was affected by surfactant content when concentration is lower than CMC. Subsequently, counter-ionic strength (by adding NaSal) was discovered to have a positive effect on PEO-HTAC system. The addition of salt resulted in the increase of HTAC micelle size, while the hydrodynamic radius of PEO-HTAC aggregates due to shielding of electrostatic charges and the dissociation of multi-chain complexes.

3.5.2 Interactions between Anionic Polymers with Surfactants

The complexation between a charged micelle and an oppositely charged polymer has been studied extensively by various methods for several years.

On the basis of Monte Carlo simulations and thermodynamic integration, the presence of polyelectrolyte, the rigidity and the linear charge density of polyelectrolyte are found to reduce critical micelle concentration (CMC) and critical aggregation concentration (CAC). Wallin and Linse[77], [78] also suggested one simple model for this investigation.

The polymer size effect was reported by Liu et al.[79]in a alkylpyridinium(C_{12} and C_{14}) chloride and sodium poly(aspartate) system. They found polymer chain length played an important role in determining the binding constant in polymer-surfactant system when there were less than ca. 35 binding sites. Theoretical works were also done to verify the conclusion drawn by experimental works.

Thalberg et al.[80]analyzed and calculated phase behavior in a Tetradecyltrimethylammonium Bromid (TTAB, cationic)-Hyaluronan (NaHy, anionic)-water system. One phase separation model was proposed to indicate equilibrium conditions and the binding behavior of surfactant onto polymer was explained as well.

Techniques like fluorescence, conductivity, surface tension, turbidity, electron paramagnetic spectra (EPR) and viscosity measurements were also applied to study the associations of polymer-surfactant system. Kogej and Skerjanc[81] observed the hydrophobicity of surfactant would affect the critical aggregation concentration (CAC) which is lower than the critical micelle concentration (CMC). In the alkyltrimethylammonium (C_nTMAB)-poly(styrenesulfonate) (NaPSS) system, the addition of polyions greatly reduced the mobility of surfactant ions by measuring electrolytic conductivity. Deo et al.[82]studied a system consisted of DTAB (cationic surfactant) and PMAOVE (anionic polymer) with modified hydrophobic groups. With various PH values, the interactions between PMAOVE-DTAB were found to occur in different Models, both models contains three region which has been shown in Figure 10.

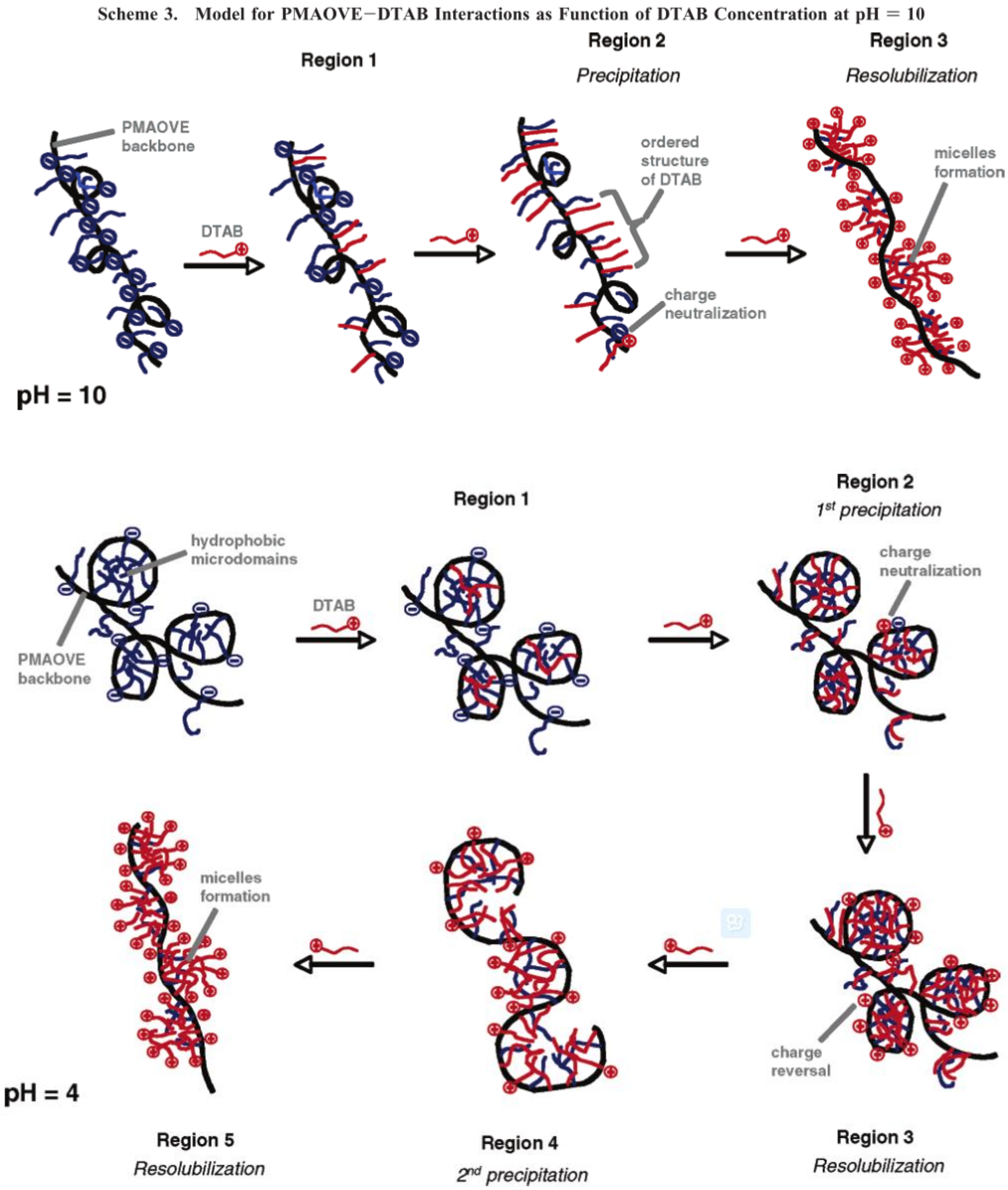


Figure 10 Models for PMAOVE-DTAB Interactions as Functions of DTAB Concentration

As for anionic polymer-ionic surfactant systems in drag reduction, Kim, Mohnisenpour and Pal et al. [83]–[85] have done a lot of contributions to this field. Kim discovered turbulent drag reduction efficiency with a combination of poly(acrylic acid) and sodium dodecyl sulfate in a rotating disk apparatus and discussed several influences on DR (PH, rotating speed, surfactant, concentration). One critical polymer concentration was reported, reaching its maximum DR percentage (about 35%). A system containing PAM and OTAC was discussed by Mohsenipour and Pal in 2013, water quality (DI or tap water) was found to be a significant factor in DR behavior of polymer solutions. Though PAM showed a good DR ability in pipeline alone, the strong interactions between PAM and OTAC reduced its DR efficiency greatly especially at low PAM concentrations.

The interactions between polymer and surfactant have been well studied and developed. While few documents focus on the interactions in drag reduction fields, especially anionic polymer with non-ionic, anionic and zwitterionic surfactants. One of our works (Chapter5) concentrates on exploring new combinations and system by anionic polymer and ionic surfactant with great DR ability. Experiments about carboxyl methyl cellulose (CMC) with six surfactants are studied both in bench-scale and pilot-scale. Chapter 6 illustrates a polymer-polymer system at fixed total polymer concentration in pipeline behaviors. Polymers and surfactants are selected according the literature survey and the limitation of laboratory.

Chapter 4
Experimental Works and Methods

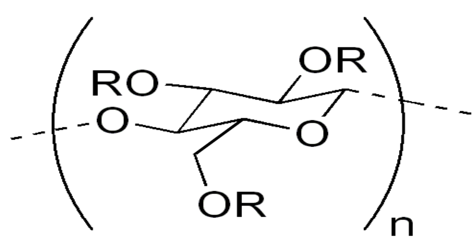
The whole research can be divided into two parts. The first part is mainly about exploratory experiments, several kinds of surfactants with polymer solutions were studied specifically. In the second part, a combination of two polymers PEO with PAM was focused on, in order to see whether there exist positive interactions between them with respect to their DR ability. As for experimental methods, both bench-scale and pilot-scale research works were carried out, which will be described in this chapter later.

4.1 Drag Reducing Agents

4.1.1 Polymers

Four different polymers were used in this research, they are CMC (carboxymethyl cellulose, PolyOX (Poly(ethylene) Oxide) and PAM (Polyacrylamide), all of them have a wide range of applications in our daily lives and are easy to access.

CMC, also known as cellulose gum is a cellulose derivative. Its cellulose backbone is make up with Carboxymethyl groups and hydroxyl groups of the glucopyranose monomers (chemical structure is shown as follows **Figure 11**). It has a wide range of applications currently, such as viscosity modifier in food, thickening agent in pharmaceuticals and characterizing enzyme activity from endoglucanases.



R = H or CH_2CO_2H

Figure 11 Chemical structure of CMC

PolyOX (PEO) is a very common polyether compound from industrial manufacturing to medicine. Lubricating coating, polar stationary phase for gas chromatography, precipitant for plasmid DNA isolation and protein crystallization are all its applications. The structure of PolyOX is quite simple as well (see **Figure 12**).

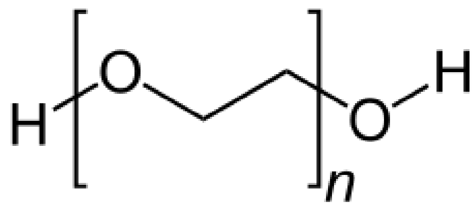


Figure 12 Chemical structure of PEO

PAM, full name is polyacrylamide, is a polymer made up with acrylamide subunits. Due to its highly-absorbent ability, it can always be utilized as gel electrophoresis. The chemical structure of PAM is as follows (see **Figure 13**).

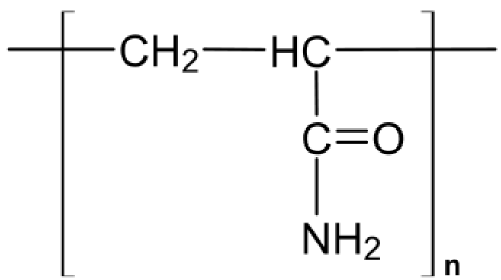


Figure 13 Chemical Structure of PAM

4.1.2 Surfactants

Six surfactants are selected in this research. Based on the categories they belong to, Alfonic 1412-3 Ethoxylate, Alfonic 1412-9 Ethoxylate and Aromox are nonionic surfactants, while Stepanol and Stepwet are anionic surfactants. Besides, Amphosol is an amphoteric surfactant (see **Table 2**).

Table 2 Lists of Surfactants

Surfactant Type	Non-ionic	Cationic	Anionic	Amphoteric
Name	Alfonic 1412-9 Alfonic 1412-3 Aromox DMC	-	Stepanol WA-100 NF/USP Stepwet DF-95	Amphosol CG

The difference between Alfonic 1412-3 Ethoxylate and Alfonic 1412-9 Ethoxylate is the length of carbon chain, which also accounts for different molecular weight range. Generally, they are all common surfactant, always used as detergent, emulsifier, soaps or for some industrial purposes.

All the detail information about these drag reducing agents are listed in **Appendix A**.

4.2 Experimental Set-ups

In the experimental part, all works are made up with bench-scale research and pilot-scale research. By combining them together, we can get a better understanding of different concentrations and combinations of polymers and surfactants solutions in pipeline behavior, especially drag reduction ability.

4.2.1 Bench-scale Experiments

In our research, surface tension, conductivity and viscosity are measured. By analyzing the results of these properties of prepared solutions, minimum concentration of interactions between polymers and surfactants can be discovered. After that, the optimized concentrations and combinations of solutions will be applied to pilot-scale experiments to calculate friction factor inside of pipelines and compared with theoretical assumptions presented by Blasius Equation in laminar regime and Dodge and Metzner Equation in turbulent regime.

Surface tension is derived from cohesive forces among liquid molecules between two surfaces. Each molecular in a bulk liquid has an equal force in every direction by neighboring liquid molecules, resulting a net force of zero. While the molecule on the surface has a different situation. They do not have a same amount of neighbor molecules on all sides of them, which makes they cohere more strongly to those associated with them and forces liquid surface to the minimal area. The minimum spherical shape of a liquid droplet and minimum gravitational potential energy are common phenomena resulting from surface tension. Two measuring methods were applied to test surface tension of prepared solutions. The first one is named Du Noüy Ring method. The force required to detach the ring from the liquid surface can be precisely measured and then convert to surface tension.

$$W_{total} = W_r + 4\pi R\gamma = W_r + 2l\gamma \qquad \textbf{Equation 4.1}$$

The scheme of tensiometric method for liquid surface tension determination can be explained by **Figure 14** and Equation 4.1, where the total force to pull the ring out of surface is equal to ring weight (W_r) plus two times of surface tension ($l\gamma$).

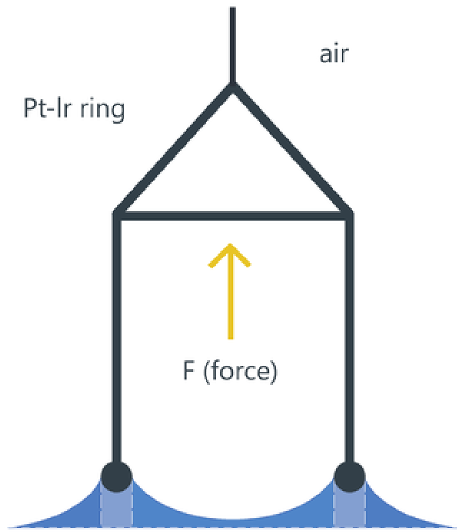


Figure 14 Scheme of tensiometric method for liquid surface tension determination

Du Noüy Ring method is easily affected by surroundings, in order to get a more accurate result, Axisymmetric Drop Shape Analysis (ADSA) is used to estimate surface tension. In equilibrium, the gravity tends to elongate a pendant drop or flatten a sessile drop to determine the shape of a drop. While surface tension has a tendency to keep the drop spherical. The balance between gravity and surface tension is governed by the Laplace equation of capillary. By photographing the shape of liquid drops with an increase of time, area, volume and apex curvature of the drop will be obtained, thus surface tension can be calculated by inversely solved the Laplace equation. **Figure 16** (a) is a schematic diagram of experimental setup of ADSA for analyzing the change of surface tension. Our purpose is to study the trend of interactions between polymer and polymer, polymer and surfactant.

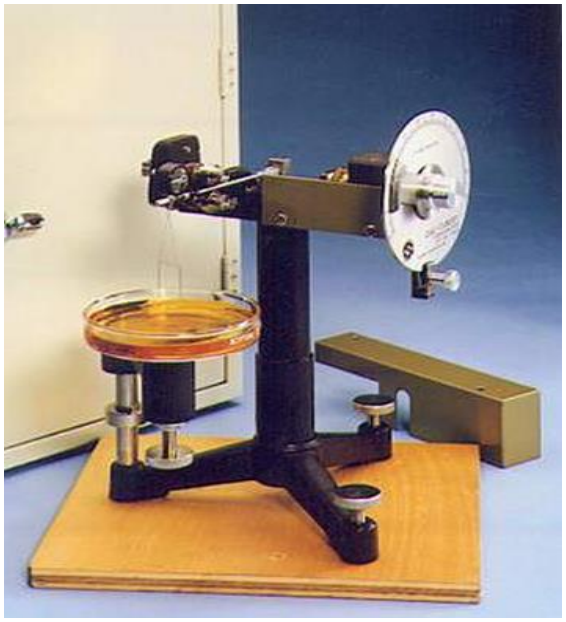


Figure 15 duNouy Tensiometers (from CSC Scientific Company Inc.)

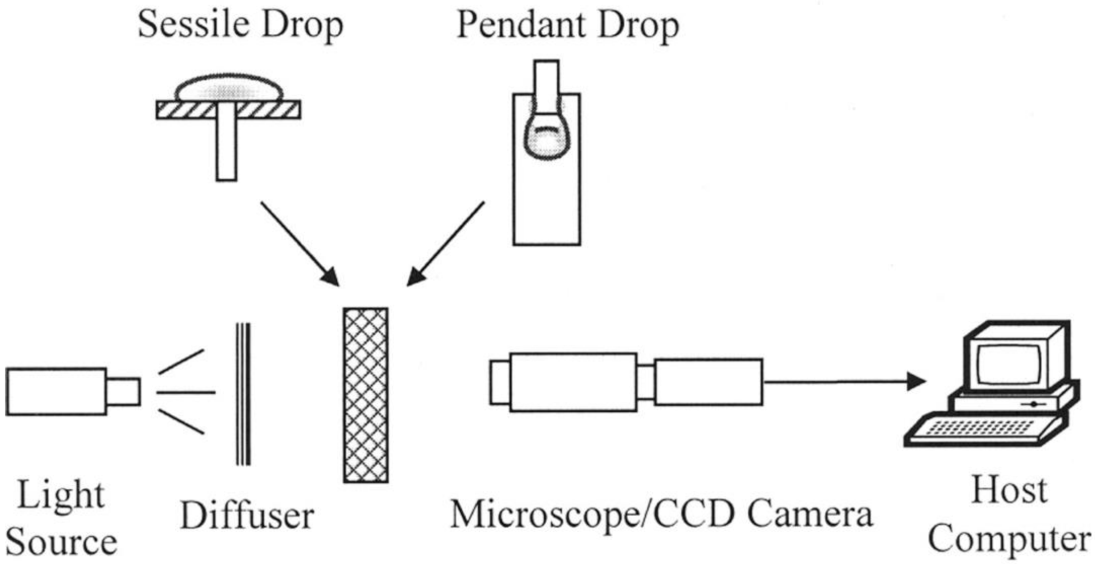


Figure 16 (a)

Figure 16 Schematic Diagram of the Experimental Setup of ADSA for analyzing Surface Tension of drops (From Hoorfar [86]**)**

Another factor that counts is conductivity, which is because the polymer saturation point (PSP) and critical aggregation concentration (CAC) can be discovered by it. Conductivity is an ability of a fluid to let an electrical current pass and is greatly affected by inorganic irons. Also, temperature may influent conductivity as well, for this reason, fluid we prepared are always tested at 25 degrees (25℃). Orion 3 star plus conductivity meter was utilized to conduct measurement.

Also, viscosity is very significant in our research. Laminar flow and turbulent flow are two flow regimes in fluid dynamics, when increasing the Reynolds number, laminar flow will convert to turbulent flow. In turbulent flow, viscosity is easily to dampen Re which means it would be more difficult for a fluid with a higher viscosity to form a turbulent flow. For this reason, viscosity was determined by Ubbelohde viscometer and coaxial cylinder viscometer specifically. The definition of relative viscosity and specific viscosity is easily shown by Equation 4.2, 4.3.

Relative viscosity

$$\boldsymbol{\eta_r = \frac{t_f}{t_w}}$$ **Equation 4.2**

Specific viscosity

$$\boldsymbol{\eta_s = \frac{t_f - t_w}{t_w}}$$ **Equation 4.3**

The mean flow time of a solution (t_f) is measured using Ubbelohde viscometer which is compared with water flow time (t_w). It is based on capillary method and is recommended for higher viscosity cellulosic polymer solutions.

Coaxial cylinder viscometer also was used to measure the shear viscosity. When rotating, the bob was fixed and rotor would rotate. The basic information of viscometer is shown on **Figure 17** and **Table 3**.

Table 3 Bob and Rotor Dimensions (derived from Dr. Ali's thesis)

	OD(MM)	LENGTH(MM)	ID	THICKNESS(MM)
BOB	34.5	45.12		
ROTOR	40.67	87.33	36.76	1.96

For Newtonian and Non-Newtonian fluids, different equations were applied to calculate shear rate.

For Newtonian fluid, $$\gamma_{Ri} = \frac{2S^2}{S^2-1}\Omega_0$$ **Equation 4.4**

For Non-Newtonian fluid, $$\gamma_{Ri} = \frac{2N}{1-S^{-2N}}\Omega_0$$ **Equation 4.5**

Where, $$\Omega = 2\pi(rpm)/60$$ **Equation 4.6**

S is the ratio of rotor radius to that of bob (R_0/R_i=1.067845) and N is the slope of LnΩ versus Ln(torque) for the viscometer.

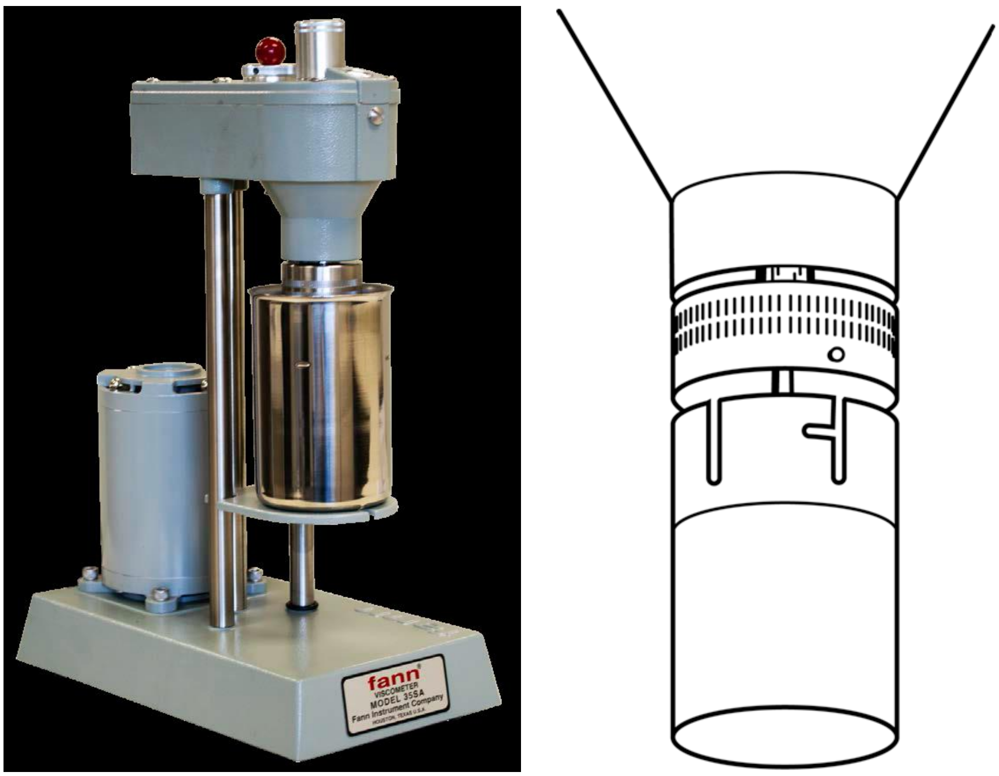


Figure 17 Coaxial cylinder viscometer

In order to measure shear viscosity, the stainless cup (see figure) need to be filled up to a test level and the bob and rotor should be merged into the test solution up to a scribe line. By changing the rotor speed, different shear rates can be produced and the results can be read on the dial-reading. The shear stress can be calculate by Equation 4.7.

$$\tau = 0.0881 \times (\text{dail reading}) - 0.3694(\text{Pa})$$ **Equation 4.7**

Detail information about these instruments utilized are listed in **Appendix B**.

4.2.2 Pilot-scale Experiments

The pilot-scale experiments were conducted in a closed loop system, the details can be discovered from a schematic diagram (**Figure 18** (a)) and a photo of the pipeline set-up (**Figure 18** (b)). After analyzing the result of bench-scale experiments, some concentrations and combinations of test fluid were selected and prepared in the main tank mixing by a stirrer. A temperature controller and a heating/cooling coil were installed in order to maintain a constant temperature throughout the experiments. Because some of the chemicals are surface active, after several hours' preparation, there will be a large amount of foams and bubbles on the surface of the tank, which may affect the pipeline results to a large extent. The prepared fluids are required to be kept still overnight to avoid the foams and bubbles.

Beside the main tank, a centrifugal pump was connected to ensure the circulation of solutions in the loop. The mass of flow were controlled by Coriolis flowmeter. In order to measure the effect of tube diameters, the test section was consisted of 1inch and 1.5inch straight horizontal-installed pipelines. There were two test points on both of the pipelines. The first one was regarded as reference tap. By calculating the differential pressures between two points, the pressure loss could be collected. Specifically, pressure transducers were installed at test point and the signal would be processed by data acquisition system using LABVIEW software. One thing need to mention was that the test points must be selected far enough away from pipeline entrance to ensure the test fluid in pipeline is fully developed. The tube dimensions and test point locations are shown on **Table 4**.

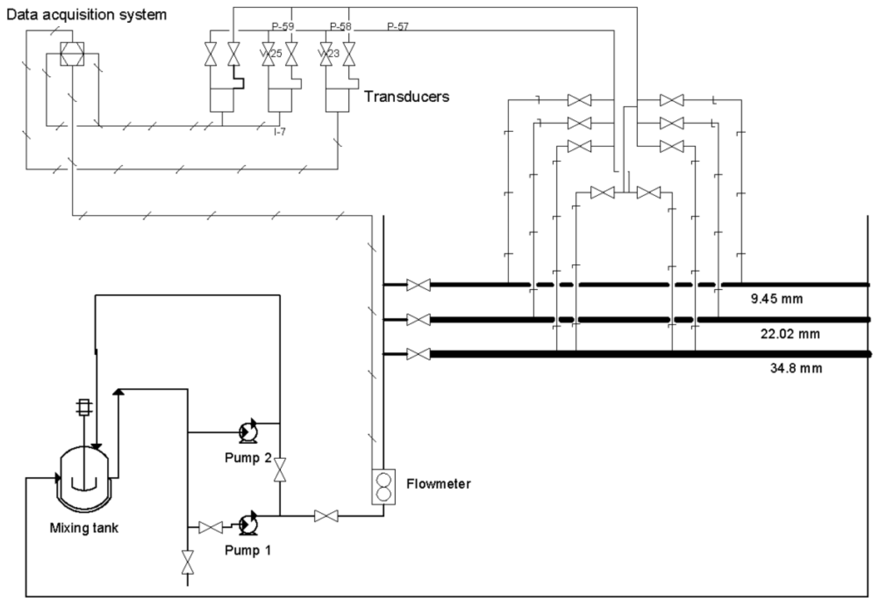


Figure 18 (a) pipeline diagram

Figure 18 (b) mixing tank photo

Figure 18 (c) control system and pipeline photo

Figure 18 pipeline diagram and set-up photos (From Mohsenipour[5]**)**

Table 4 Tube Dimensions and Test Point Locations

PIPE #	NOMINAL DIAMETER (INCH)	INNER DIAMETER (MM)	ENTRANCE LENGTH (MM)	TEST SECTION LENGTH (M)
1	1	22.02	154.2	0.9104
2	1.5	34.8	154.2	3.048

For Coriolis flow meter, calculations have been done by Dr. Mohsenipour and the equation used for mass flowmeter is,

$$\boldsymbol{Mass\ flow\ (KgS^{-1}) = 1.534 \times (Reading\ Volt) - 1.5272} \qquad \textbf{Equation 4.8}$$

For pressure transducers, two with different measurement ranges were installed. Each transducer was connected with two shut-off valves and one bypass valve to ensure the whole measuring process. Pressure differences are collected by data-acquisition system via voltage output. Calibration works have been done by Dr. Mohsenipour as well. The schematic diagram for transducer-valve connection is shown in **Figure 19**.

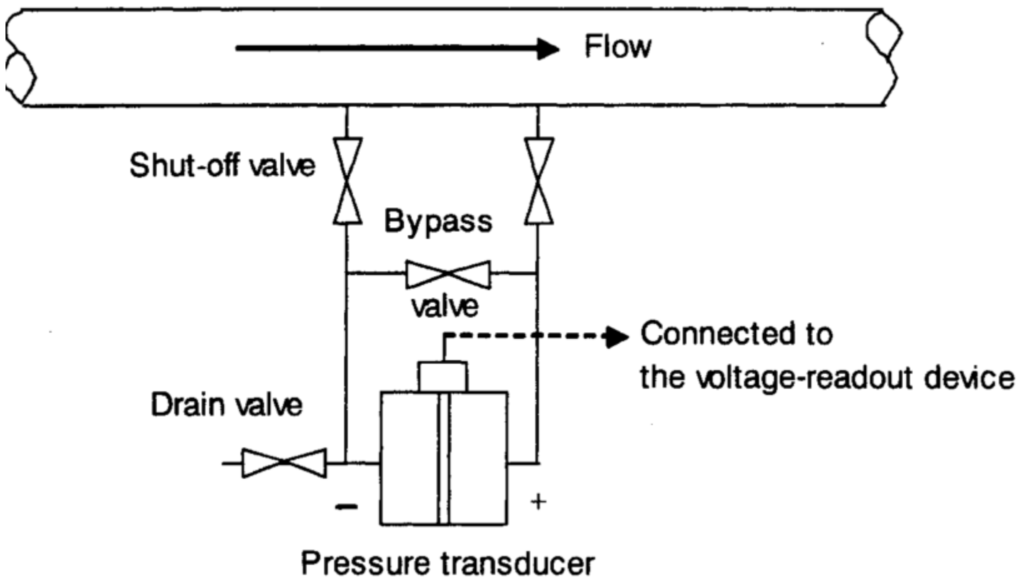


Figure 19 Schematic Diagram for Transducer-valve Connection (from Kim (2003))

The pressure transducer output equations are listed in **Table 5**,

Table 5 Pressure Transducer Output Equations

RANGE	DIFFERENTIAL PRESSURE (DP)
0-5 PSI	DP=1.2581×(Reading Voltage)-1.2823
0-0.5 PSI	DP=0.1221×(Reading Voltage)-0.102

Appendix C are all the data we measured during the whole research. A calculation sample of how to get the %DR is also provided in **Appendix D**.

Chapter 5
Polymer-surfactant Studies

Several combinations and concentrations were investigated in order to find a good drag reduction system which has a strong drag reduction ability as well as economic efficiency. The temperature was fixed at 25℃ in both bench-scale and pilot-scale experiments. A mixed drag reduction system consisting of anionic polymer and cationic surfactant has been studied in the past. However, little work has been reported on the interactions anionic polymer with non-ionic, anionic and amphoteric surfactants, especially in pipeline performance.

Carboxylmethyl cellulose (CMC) is an anionic polymer with a strong DR ability[7], [10]. In this study, CMC was selected as a polymer additive and six surfactants were added into the CMC solution to prepare a new polymer-surfactant solution which would be applied to pipelines to test drag reduction behavior and performance. The measured data were compared with the Blasius Equation which is valid for Newtonian fluids (water) and the Dodge-Metzner curve which is valid for non-Newtonian fluids. After these comparisons, the %DR were calculated and several conclusions could be made. All the surfactants selected were water-soluble and were expected to have some interactions with polymer.

5.1 Pure CMC Solutions

5.1.1 Bench-scale Results

Surface tension, conductivity and viscosity were measured to determine the properties of solutions to be tested in the pipeline in our bench scale experiments. Detailed procedures and methods have been discussed in Chapter 4.

Referring to **Figure 20**, Du Noüy Ring method was utilized in surface tension measurement. 100ppm, 300ppm, 500ppm, 700ppm, 1000ppm, 1500ppm and 2000ppm pure CMC solution were prepared. The surface tension of every fluid is believed to be constant and the data shows the same result as our expectation. From 100ppm to 2000ppm, the surface tension of CMC keeps stable around 68 dyne/cm which is because CMC is not surface-active polymer and will not have any effect on surface tension. **Figure 21** describes the relationship between conductivity and CMC concentration. Since the polymer we used in our experiments is its sodium salt, sodium carboxymethyl cellulose (anionic), the conductivity plot has a positive correlation with the concentration. When it is 100ppm, the conductivity is only 0.1395μS/cm, which is compared with 2.3205μS/cm in 2000ppm concentration.

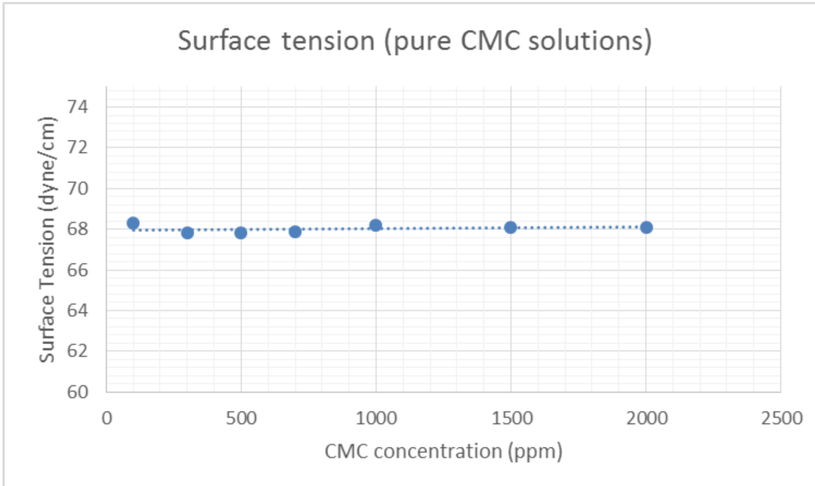


Figure 20 Surface Tension of Pure CMC Solutions

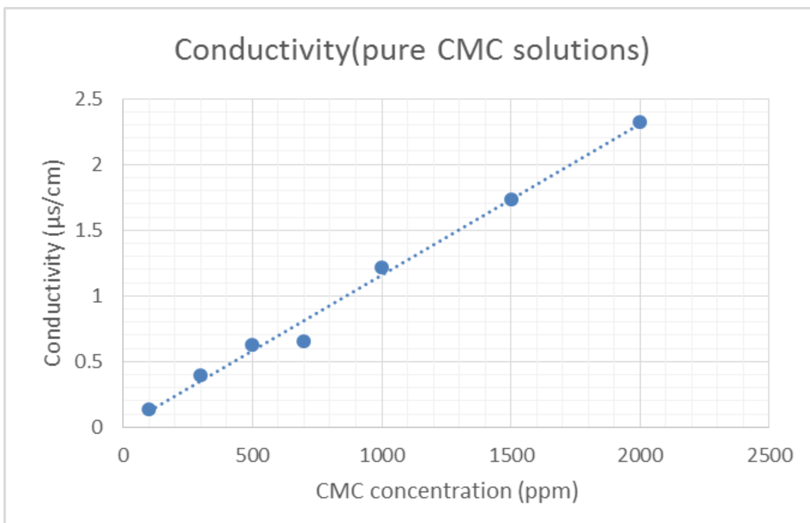


Figure 21 Conductivity of Pure CMC Solution

The shear viscosity was measured using the coaxial cylinder viscometer. The shear stress versus shear rate data were obtained from dial reading versus rotational speed. **Figure 22** shows the relationship between shear stress and shear rate. The apparent viscosity, by definition, is the ratio of shear stress to shear rate. . **Figure 23** indicates that the shear viscosity increases with the increase in the concentration of CMC solution. . At the same rotational speed, higher CMC concentration solution exhibits higher apparent viscosity. Also, increasing the shear rate, apparent viscosities show a decreasing trend, which means CMC/water solutions are shear-thinning fluids.

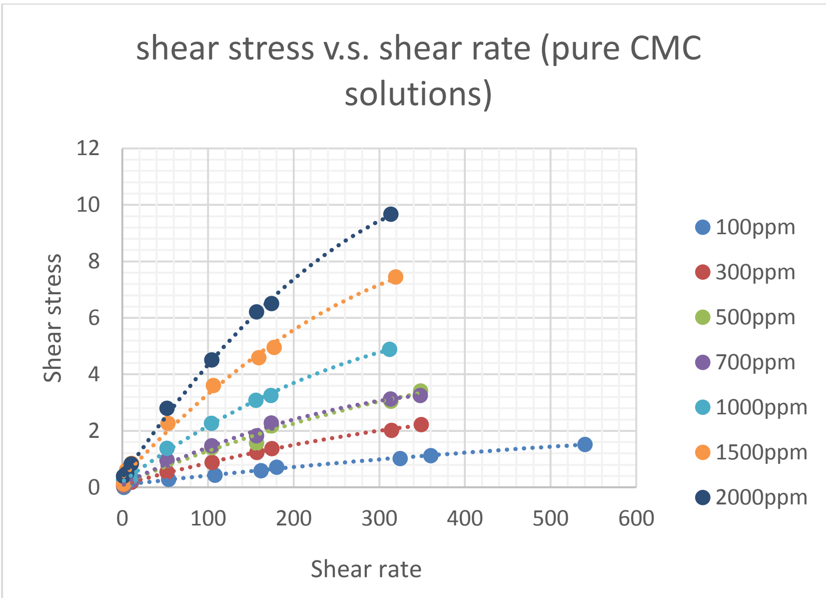


Figure 22 Shear Stress v.s. Shear Rate (pure CMC)

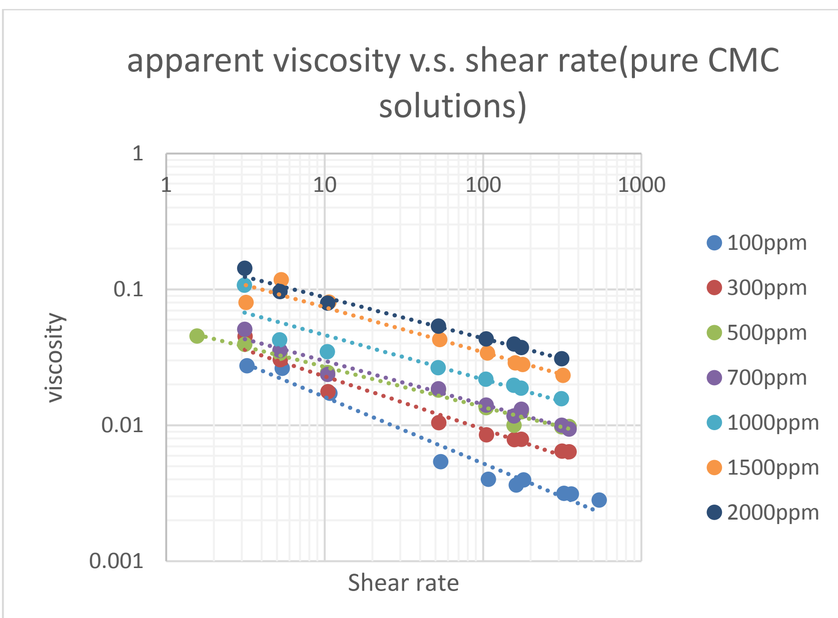


Figure 23 Viscosity v.s. Shear Rate (pure CMC)

5.1.2 Pipeline Results

As describe in Chapter 4, two different diameters (1inch and 1.5inch) pipelines were installed in our set-up to see the effect of diameter on DR. **Figure 24** (a)-(h) shows the pipeline data for different concentrations of pure CMC solutions in 1inch and 1.5inch diameter pipes.

Figure 24 (a) and (b) are 100ppm CMC in 1inch and 1.5inch pipes comparing with Dodge-Metzner Equation. It is clearly that measured data in 1inch pipe almost followed the Dodge-Metzner Equation and sometimes higher than it, which is believed no DR can be discovered at this concentration. It is the same situation in 1.5inch pipe. As for **Figure 24** (c), (d), (e), (f), (g) and (h), they describe 500ppm, 700ppm and 1000ppm CMC solution behavior in pipes. At the same Reynolds number, all of them are thought to have some DR when comparing with Dodge-Metzner friction factor (measured data are lower than Dodge-Metzner Curve). While, it is complicate to indicate whether DR occurred in contrast to solvent friction factor at the same flow rate. Because the Reynolds numbers of solvent (water in our research) are much higher than those of polymer solutions at the same flow rate. The exact %DR results will be shown afterwards.

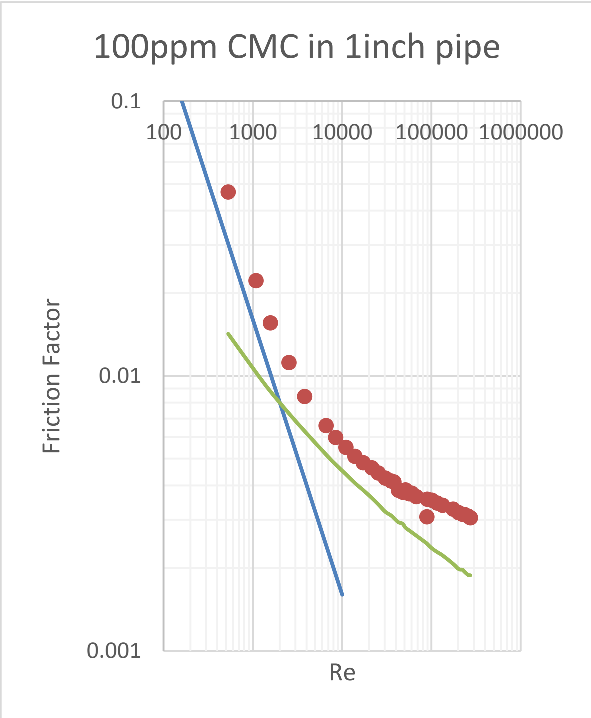


Figure 24 (a)

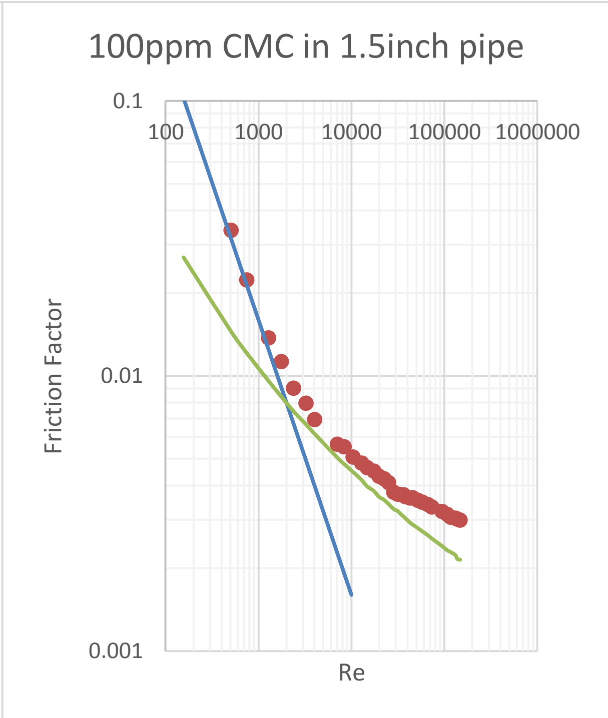


Figure 24 (b)

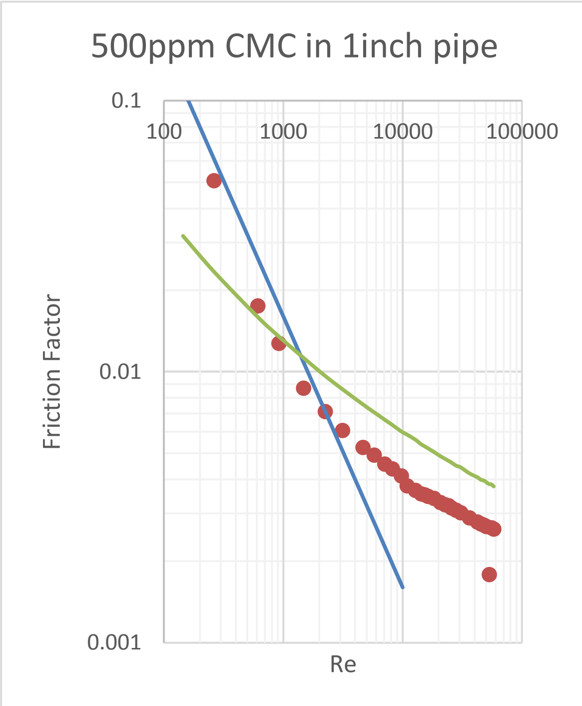


Figure 24 (c)

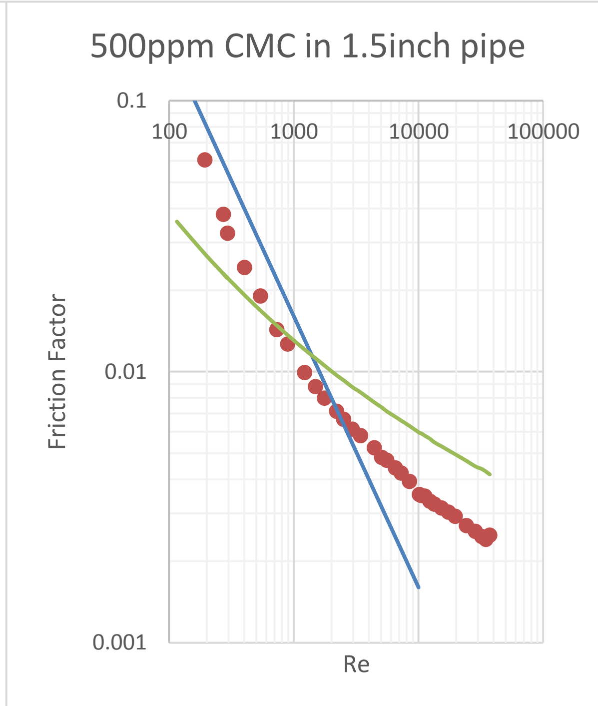


Figure 24 (d)

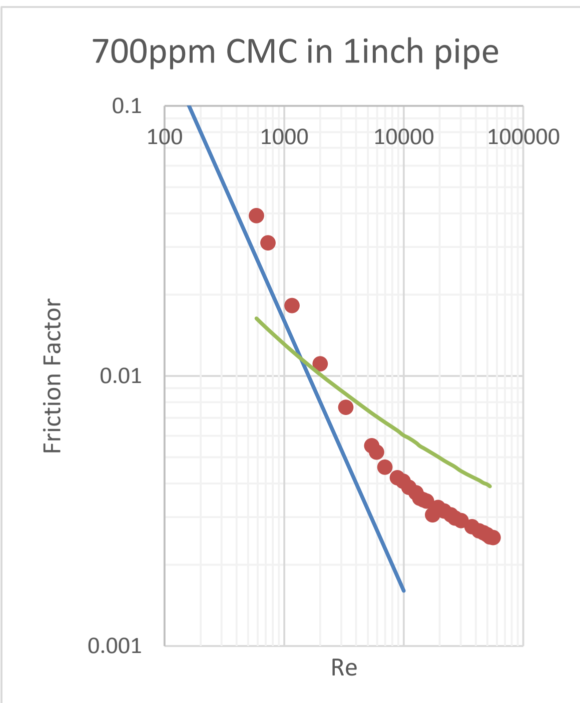


Figure 24 (e)

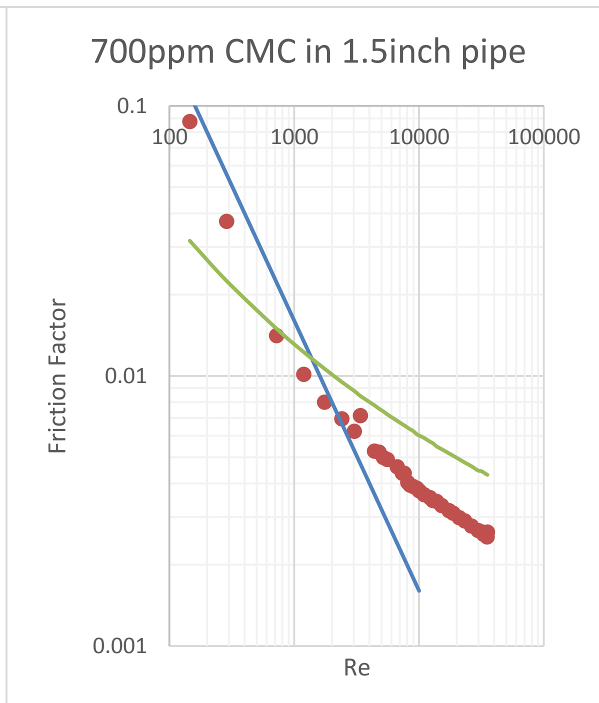


Figure 24 (f)

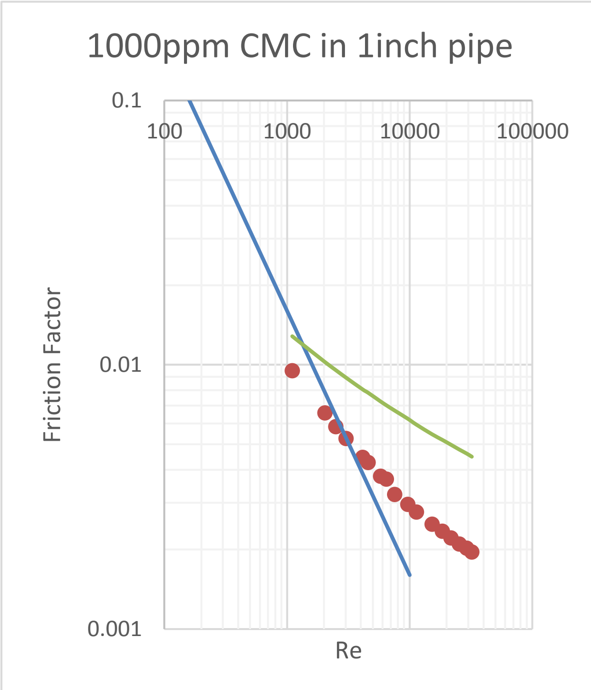


Figure 24 (g)

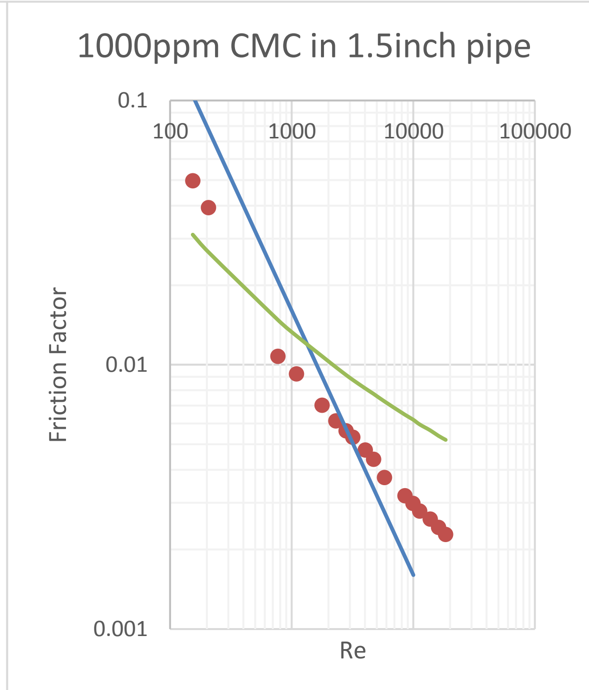


Figure 24 (h)

Figure 24 Pure CMC in Pipes

(is Laminar Flow, is Dodge-Metzner Equation, are flow data)

Figures 25 - 26 indicate the %DR when we compare measured flow data with Blasius Equation and Dodge-Metzner Equation specifically. **Figure 25** (a) and (b) show % DR for pure CMC solutions in 1inch and 1.5inch pipe when compared with Blasius Equation. There appears to be a turning point in %DR for each concentration when flow rate is around 0.0014m^3/s. Before this point, the percentage of DR increases rapidly from 0 to 20% approximately, following which a lower increasing trend with higher flow rate is observed. 100ppm CMC has its maximum %DR of about 18% in both 1inch and 1.5inch pipeline, after that, its drag reduction ability decreases gradually to 12% in 1inch and 15% in 1.5inch pipes with the increase of flow rate. When flow rate was higher than 0.004m^3/s, the drag reduction percentage of 500ppm and 700ppm CMC in 1inch pipe remain constant around 23% and 26%. While for 1000ppm CMC in 1inch pipeline, %DR goes up gradually and reaches 43% when flow rate is 0.0042m^3/s. In the same pipe, it is observed that the higher CMC concentration, the higher drag reduction ability in our experimental range. Besidesthe %DR in 1.5inch pipe has relative higher values than that of 1 inch pipe, which indicates that the tube diameter has a positive effect on %DR.

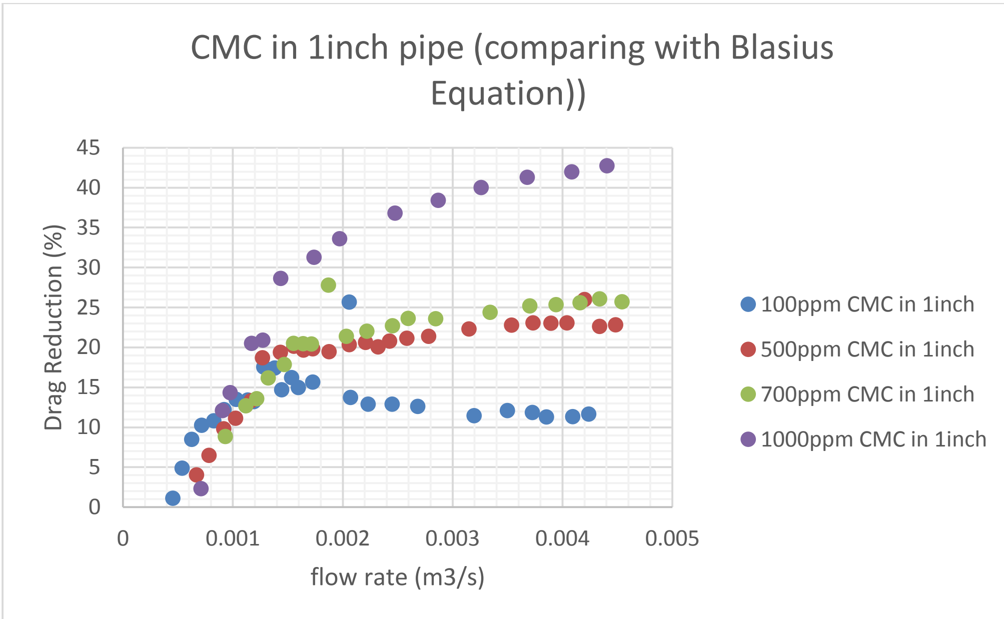


Figure 25 (a)

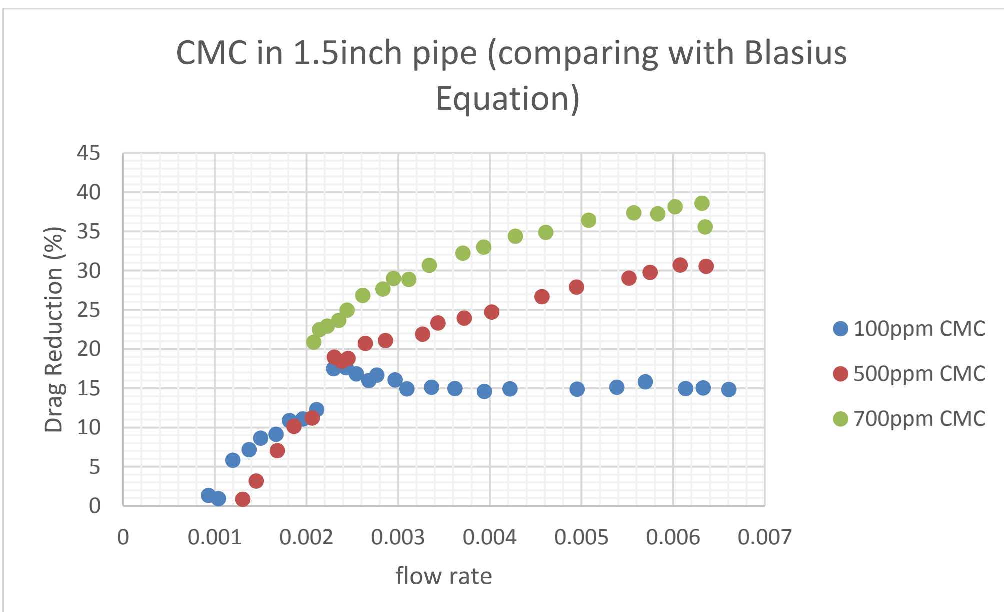


Figure 25 (b)

Figure 25 %DR of Pure CMC (comparing with Blasius Equation)

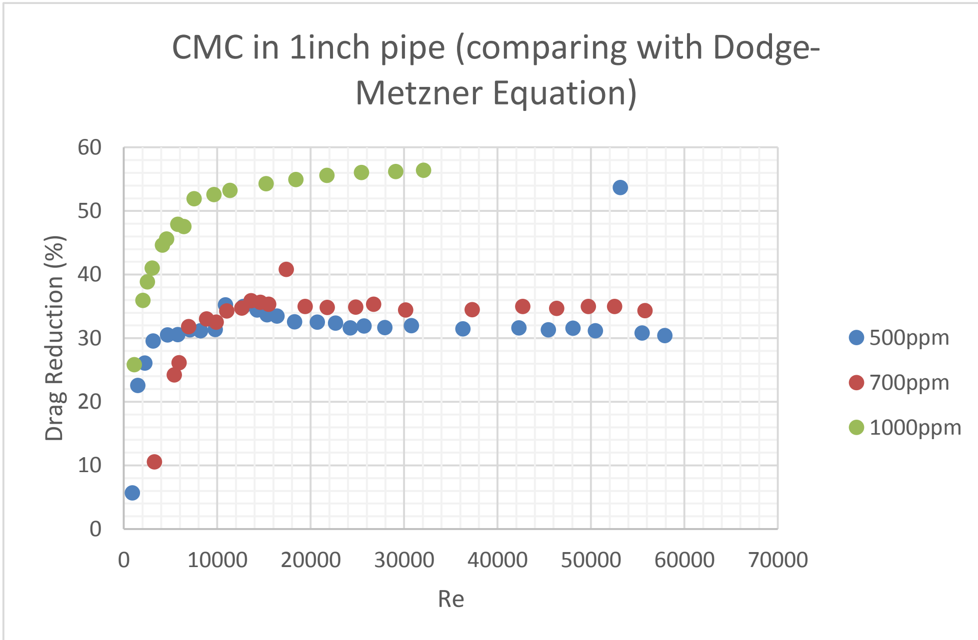


Figure 26 (a)

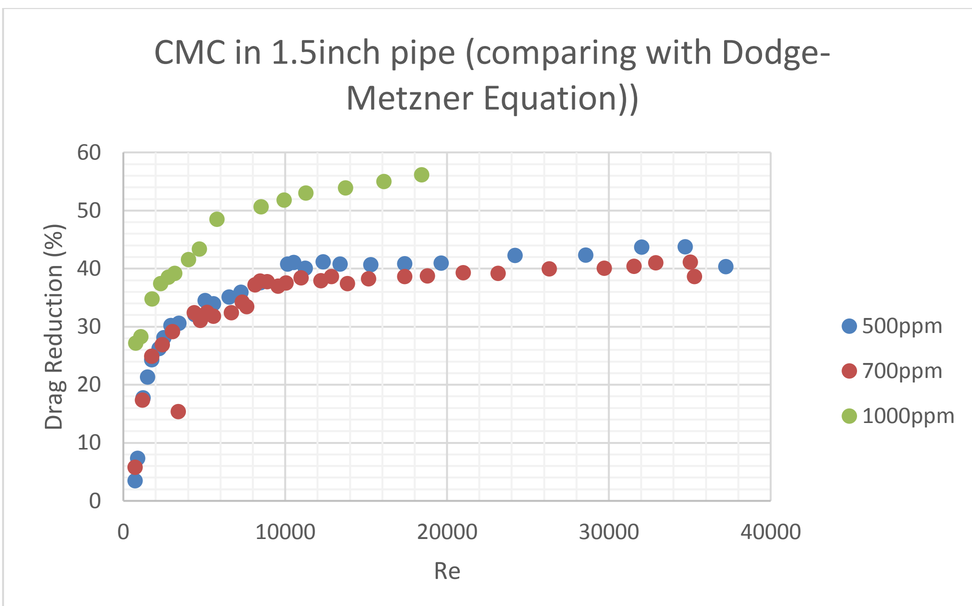


Figure 26 (b)

Figure 26 %DR of Pure CMC (comparing with Dodge-Metzner Equation)

The results obtained when comparison is made with Dodge-Metzner Equation are shown on **Figure 26.** According to Figures 26(a) and (b), when Reynolds number is lower than 5000, there occurs a sharp rise in %DR for every concentration in both pipes. With further increase in Reynolds number, %DR remains stable. 500ppm and 700ppm CMC solutions have similar %DR at high Reynolds number, which are 33% in 1inch pipe and 41% in 1.5inch. 1000ppm CMC has an obvious growth in %DR and achieves 57% in both diameters. Note that at low CMC concentration (500ppm and 700ppm) %DR is high in 1.5inch than that of 1inch pipe (41% and 33% specifically); this difference is not observed at high CMC concentration (1000ppm). In summary, solutions with high polymer concentration exhibit high drag reduction abilities. When Reynolds numbers is higher than 10000, %DR tends to become constant.

5.1.3 Conclusion

Pure CMC solution are investigated as a standard for comparison with polymer-surfactant systems later. Several conclusions can be drawn from these tests.

- High CMC concentration solutions have significant DR abilities in turbulent pipes (up to 57%) and higher polymer concentration will produce higher %DR
- Comparing with Newtonian fluid (Blasius Curve) at the same flow rate, the maximum %DR is much smaller (43%) than the Dodge-Metzner curve (57%)
- High polymer concentration has no effect on the onset of drag reduction, they all get started at almost the same flow rate/Reynolds number
- The critical points in %DR are perhaps due to the shear induced structure (SIS) under high shear stress at highly turbulent conditions, as suggested by Hoffman et al[87] . The macromolecules undergo permanent mechanical breakdown under high shear rate, resulting in the decrease of %DR.
- 500ppm and 700ppm CMC solutions exhibit similar %DR in both pipes. A significant increase in %DR occurs with the increase in CMC concentration to 1000 ppm. However, due to environmental and energy-saving concerns, most of the experimental work carried out with CMC-surfactant mixed systems was conducted using 500ppm CMC concentration.

5.2 CMC with Alfonic Ethoxylate

The combination of Alfonic 1412-7 with CMC has been studied by Kim[10] in his thesis; different concentration of CMC and surfactant were tested along with the diameter effect. In our work, Alfonic 1412-3 Ethoxylate and Alfonic 1412-9 Ethoxylate were selected as the surfactants to be mixed with the polymer CMC.

5.2.1 CMC with Alfonic 1412-9 Ethoxylate

5.2.1.1 Bench-scale Results

A comparison between pure Alfonic 1412-9 Ethoxylate solutions and different CMC concentrations with Alfonic solutions in surface tension and conductivity are presented in Figure 19 and Figure 20. Every CMC concentration with Alfonic has the same decreasing trend from 70 dyne/cm to about 38 dyne/cm at low surfactant concentrations. With further increase in surfactant concentration, the surface tension decreases gradually and remains stable at 33dyne/cm when surfactant concentrations are higher than 50ppm. A sharper decrease with lowest surface tension value occurs in pure Alfonic solutions. Also, from the surface tension curve, critical micelle concentration is estimated to be around 70ppm. With the increase in surfactant concentration, the surface tension is almost constant at 32 dyne/cm, which is similar to CMC with Alfonic solutions. As shown in the Figure, CMC/Alfonic 1412-9 system exhibits slightly higher surface tension values in the range of surfactant concentration, which is likely due to the interactions between CMC and Alfonic 1412-9.

As for the conductivity, since Alfonic 1412-9 is a non- ionic surfactant, CMC concentration is the most critical factor in determining the conductivity. Higher CMC concentration gives higher conductivity values. The conductivity value of pure Alfonic is extreme low which is approaching 0 practically. From conductivity results, no obvious interaction can be observed.

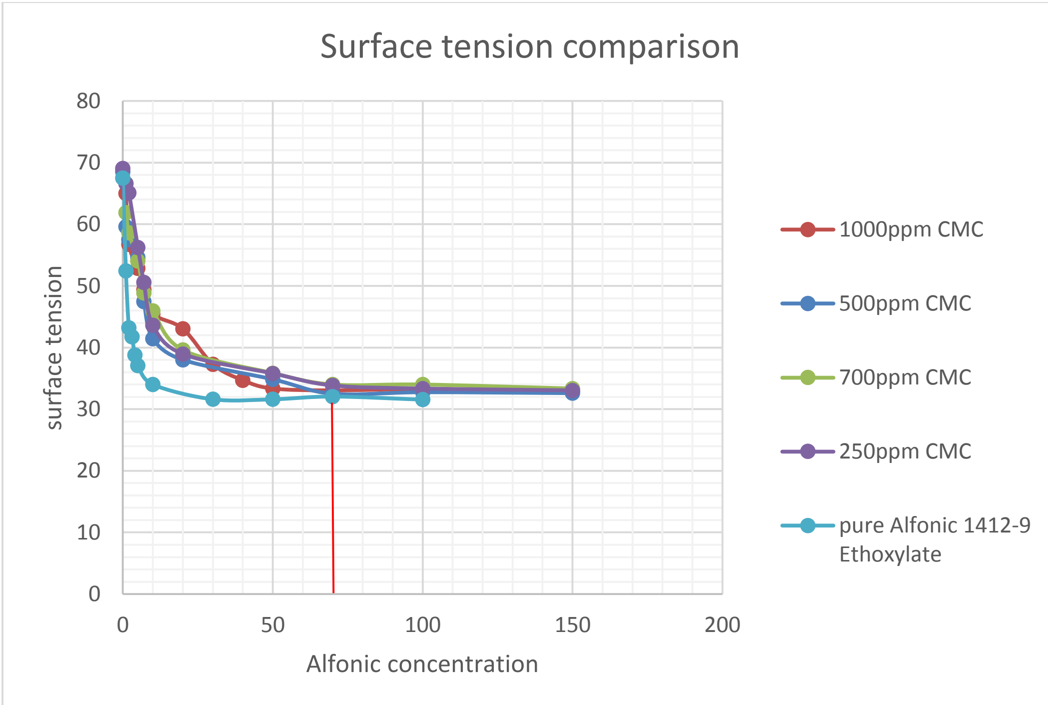


Figure 27 Surface Tension Comparison (CMC+Alfonic 1412-9 Ethoxylate)

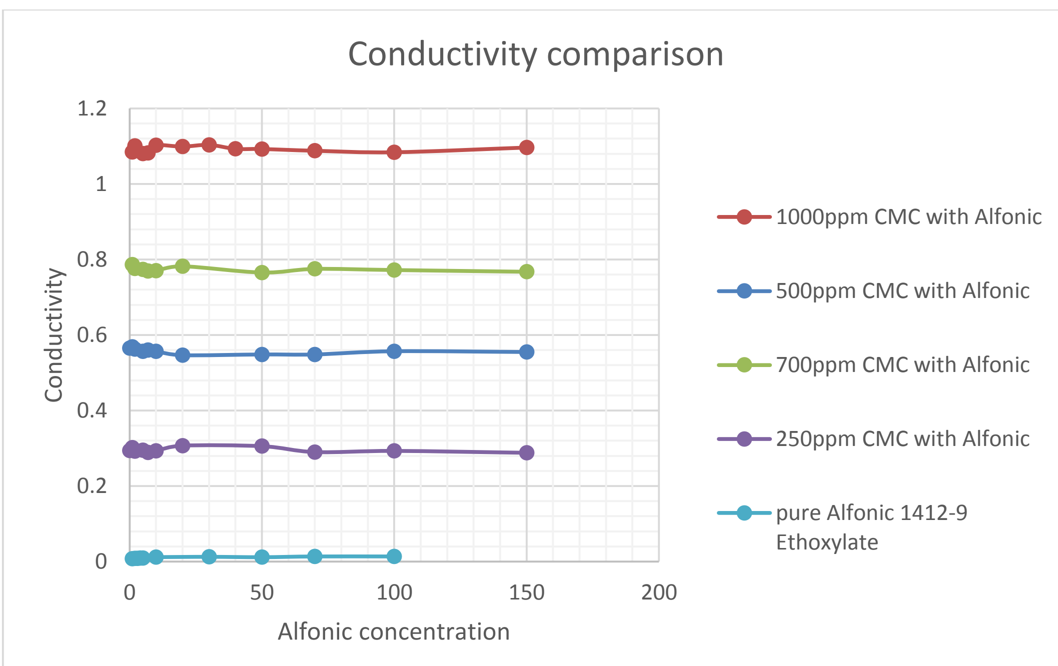


Figure 28 Conductivity Comparison (CMC+Alfonic 1412-9 Ethoxylate)

5.2.1.2 Pipeline Results

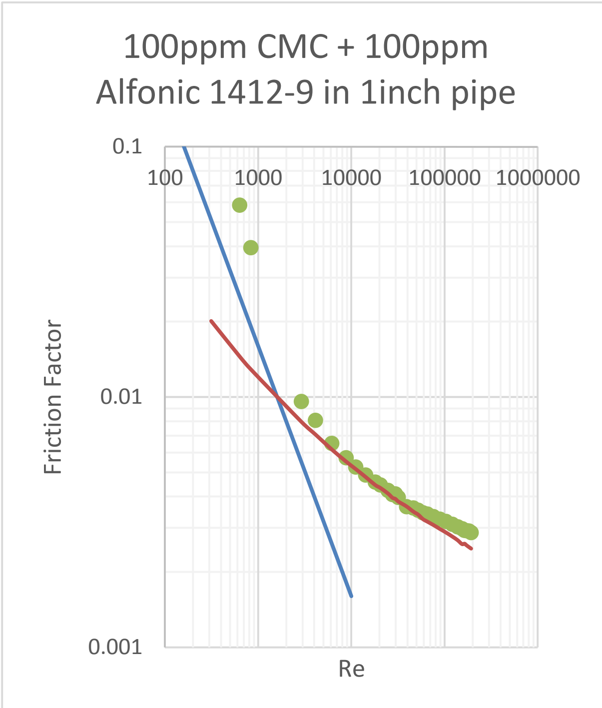


Figure 29 (a)

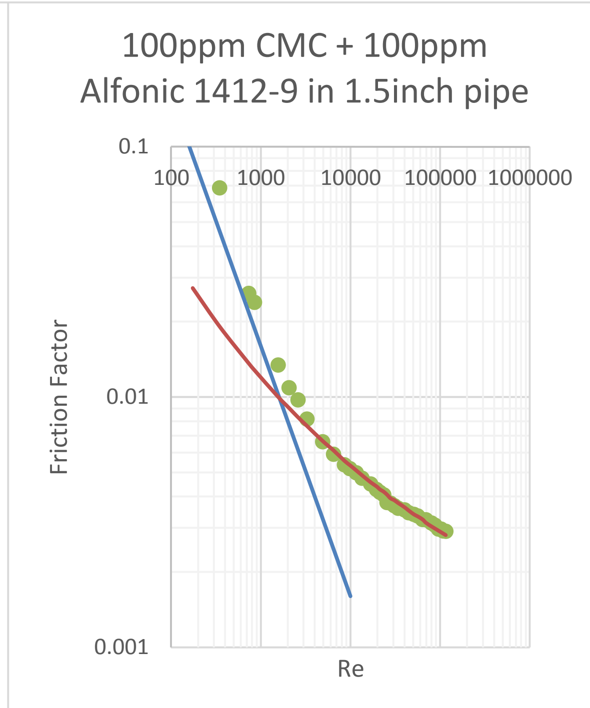


Figure 29 (b)

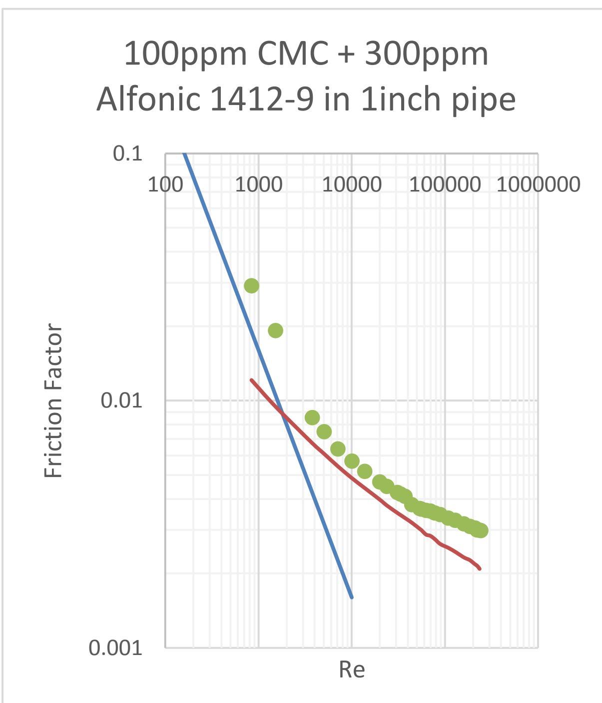


Figure 29 (c)

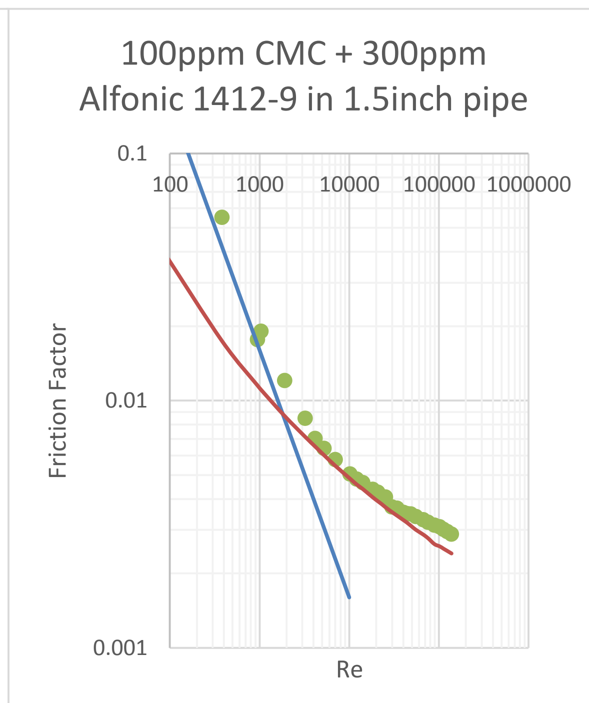


Figure 29 (d)

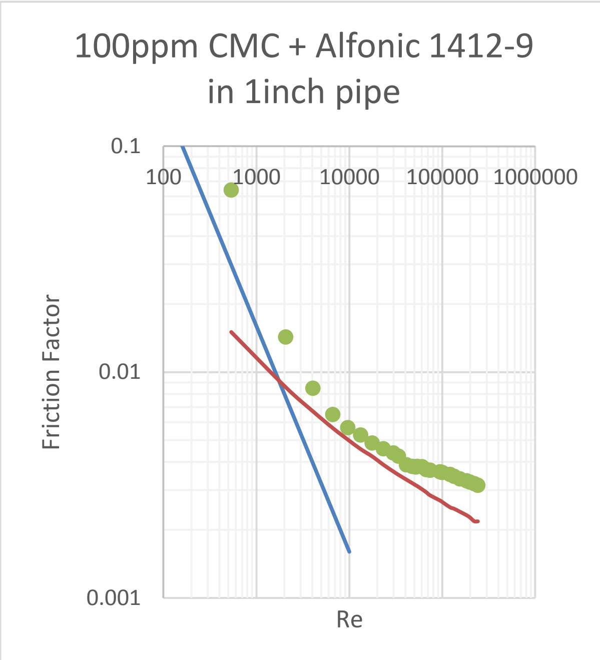


Figure 29 (e)

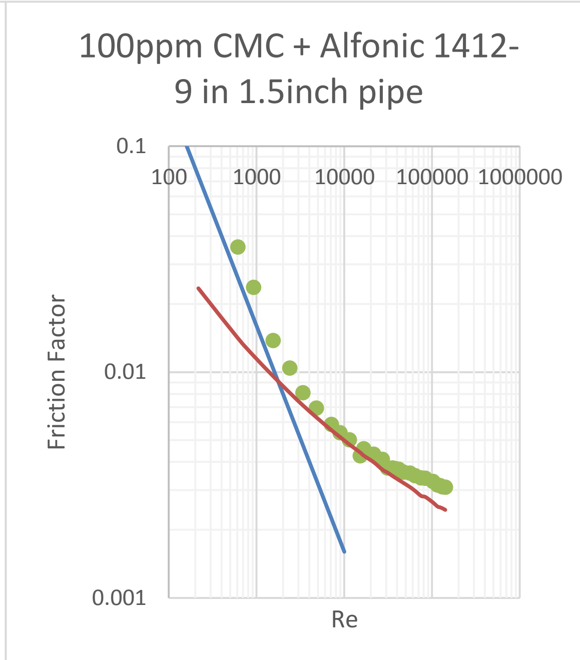


Figure 29 (f)

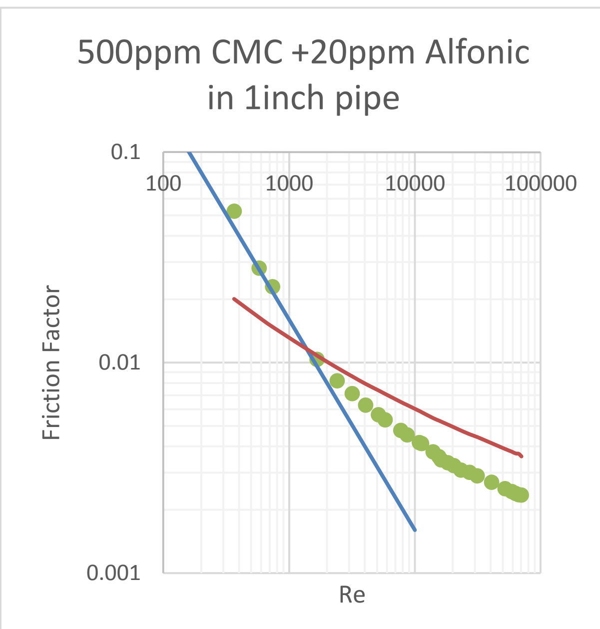


Figure 29 (g)

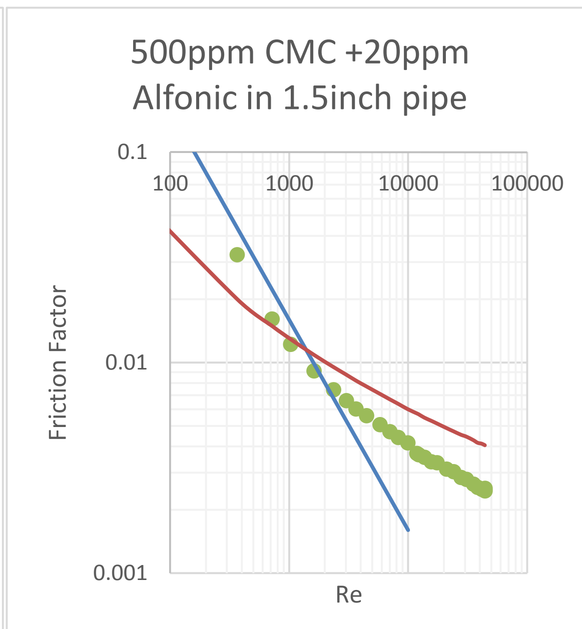


Figure 29 (h)

Figure 29 CMC + Alfonic 1412-9 Ethoxylate Pipeline Behavior

(is Laminar Flow, is Dodge-Metzner Equation, are flow data)

Figures 29 (a) to (h) present the pipeline behavior of CMC + Alfonic 1412-9 Ethoxylate system with respect to Reynolds number. 100ppm CMC with 100ppm, 300ppm and 500ppm Alfonic flow data are shown on the first 6 graphs. The other two describe that of 500ppm CMC +20ppm Alfonic solutions. It is obvious that when polymer concentration was low (100ppm) the flow data followed the Dodge-Metzner Equation, thus no DR could be obtained when comparison is made with D-M equation. At a high polymer concentration, a significant DR is observed as shown in **Figures 30** and 31.

When comparison is made with Blasius Equation, in 1inch pipe, 500ppm CMC solution shows a high %DR no matter what concentration of surfactant is. The presence of a small amount of Alfonic in polymer solutions cause higher DR ability which is discovered upon comparing pure 100ppm CMC solutions with 100ppm CMC solutions with 100ppm, 300ppm Alfonic 1412-9 and pure 500ppm CMC solutions with 20ppm Alfonic 1412-9. When the concentration of Alfonic 1412-9 reaches 500ppm and the CMC remains at 100ppm, a decrease of %DR takes place when flow rate is greater than 0.00014m^3/s. The %DR remains constant around 9% which is lower than that of pure 100ppm CMC concentration (13%). In a 1.5 inch pipe, a similar behavior occurs at low polymer concentration (100ppm). When CMC concentration is 500ppm, no effect on DR can be found by 20ppm Alfonic 1412-9 in a 1inch pipeline. Overall, CMC with Alfonic 1412-9 system in 1.5 inch pipe have a higher %DR than that in a 1inch pipe.

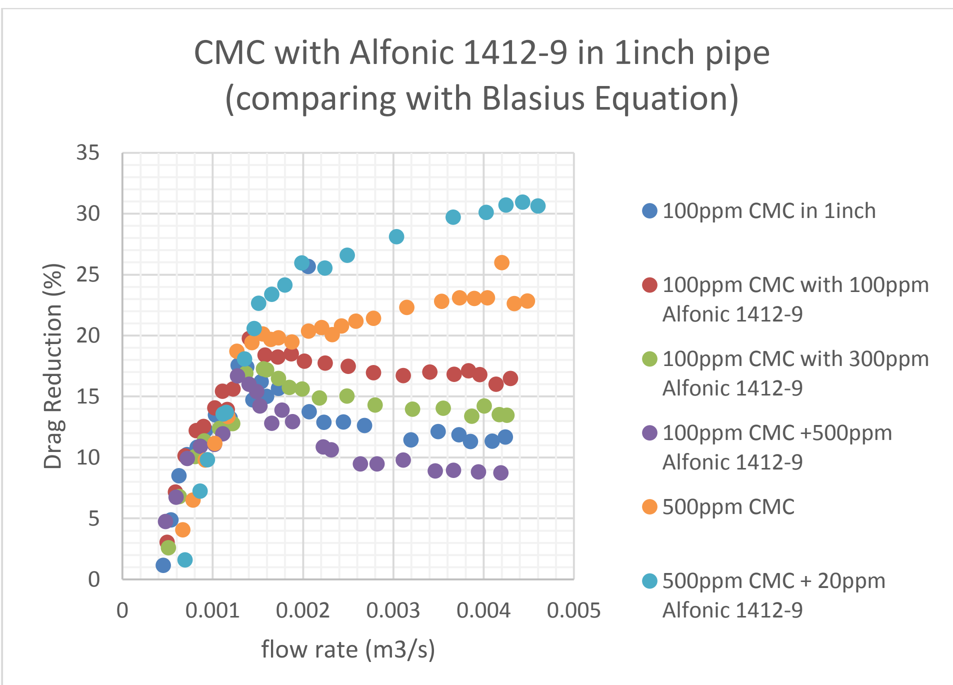


Figure 30 (a)

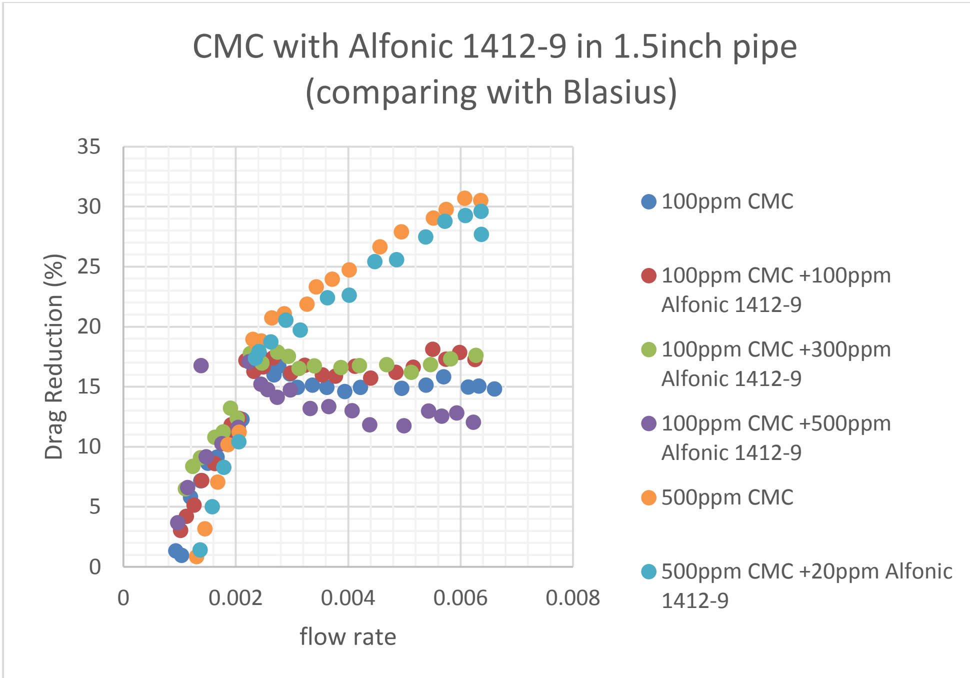


Figure 30 (b)

Figure 30 %DR of CMC with Alfonic 1412-9 (comparing with Blasius Equation)

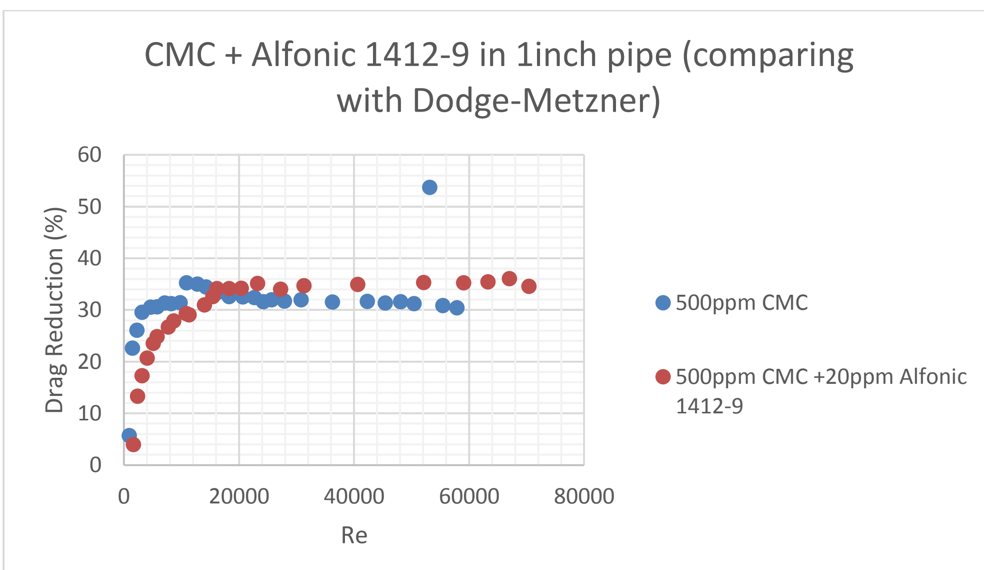


Figure 31 (a)

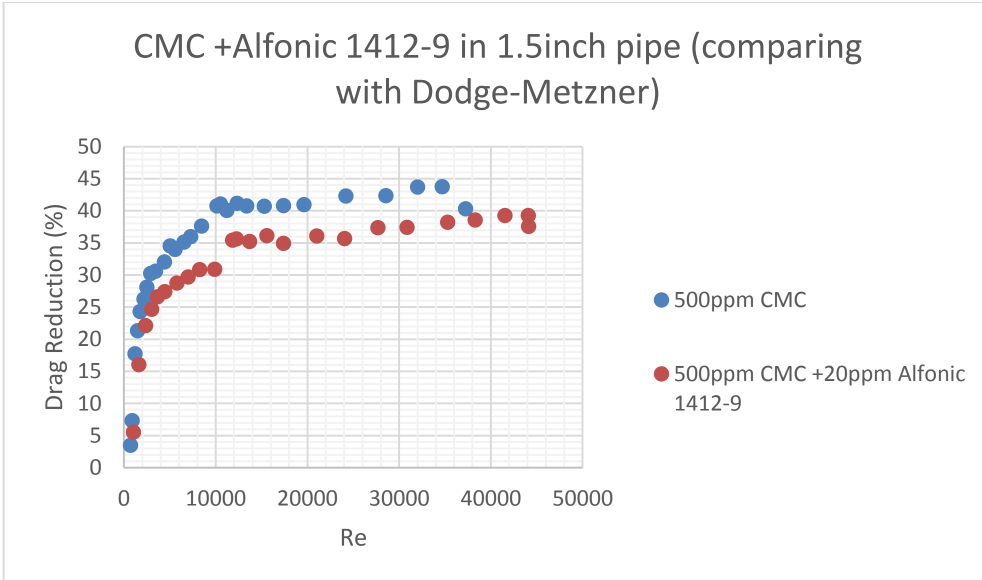


Figure 31 (b)

Figure 31 %DR of CMC with Alfonic 1412-9 (comparing with Dodge-Metzner Equation)

5.2.2 CMC with Alfonic 1412-3 Ethoxylate

5.2.2.1 Bench-scale Results

Figure 32 and **Figure 33** illustrate surface tension and conductivity of CMC with Alfonic 1412-3 Ethoxylate system. With the addition of Alfonic 1412-3, some differences in surface tension are found among 250ppm, 500ppm, 700ppm and 1000ppm CMC solution which is caused by the aggregation of polymer and surfactant. The electrical conductivity is only affected by CMC concentration due to non-ionic nature of Alfonics.

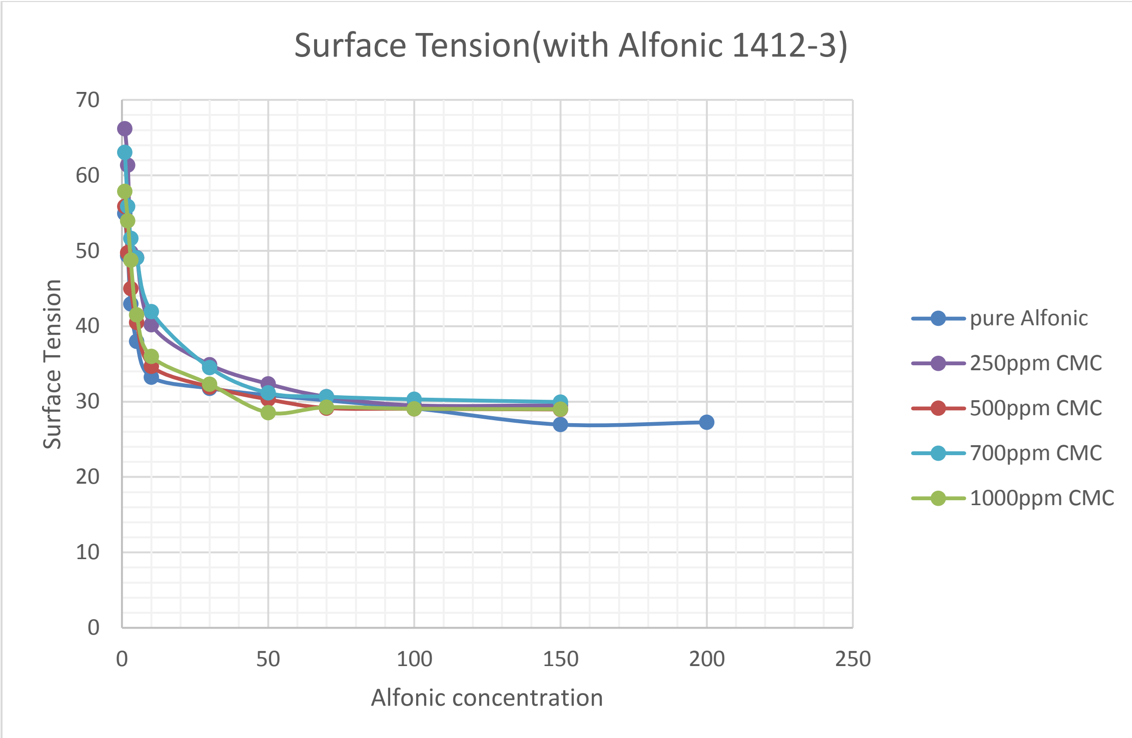


Figure 32 Surface Tension (CMC with Alfonic 1412-3 Ethoxylate)

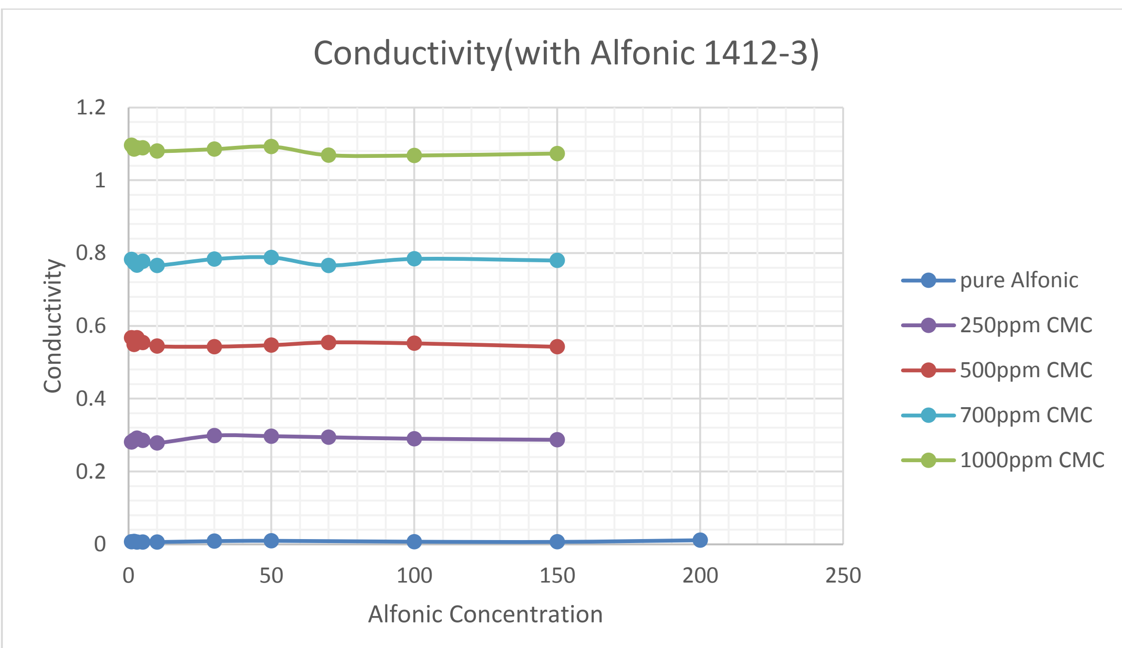


Figure 33 Conductivity (CMC with Alfonic 1412-3 Ethoxylate)

5.2.2.2 Pipeline Results

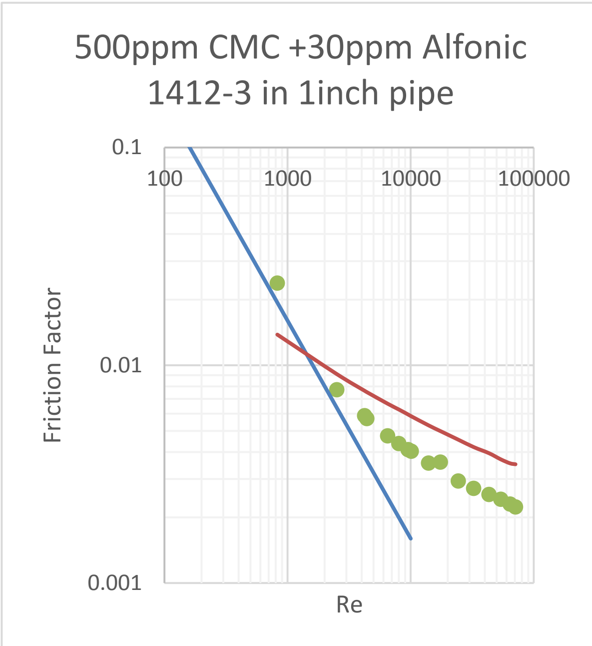


Figure 34 (a)

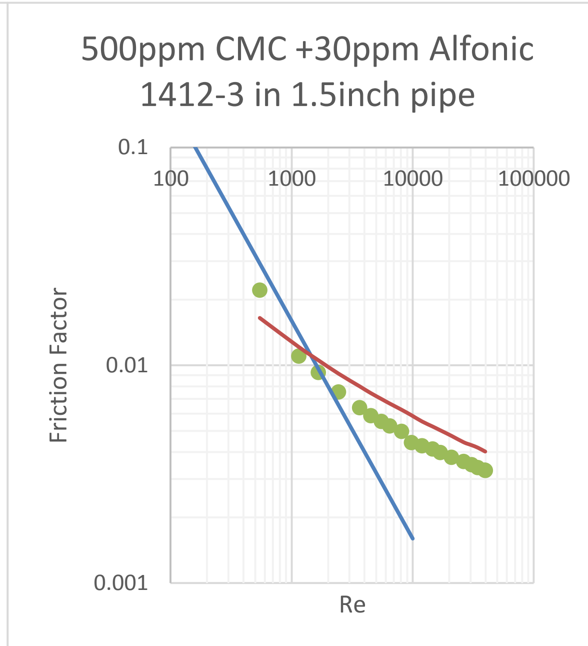


Figure 34 (b)

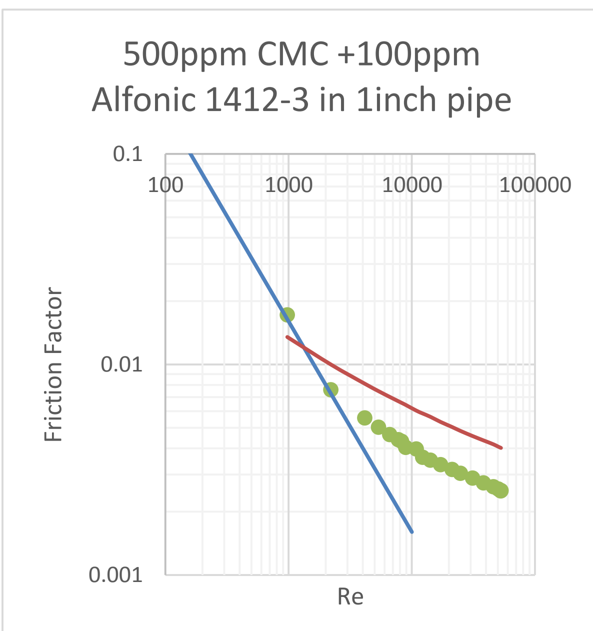


Figure 34 (c)

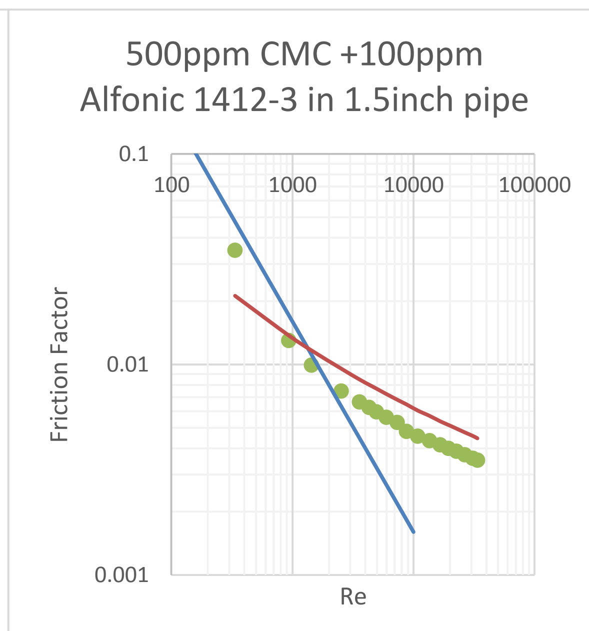


Figure 34 (d)

Figure 34 CMC +Alfonic 1412-3 pipeline behavior

(▬ is Laminar Flow, ▬ is Dodge-Metzner Equation, ● are flow data)

Figure 34 (a) (b) (c) and (d) presents the pipeline flow data of 500ppm CMC solutions with 30ppm and 100ppm Alfonic 1412-3 Ethoxylate solutions in 1 and 1.5 inch pipes. Comparing with the Blasius Equation at the same flow rate, % DR are calculated and shown in Figure 35. According to **Figure 35(a)** which is for 1inch pipeline, when polymer concentration is 500ppm, 30ppm Alfonic 1412-3 Ethoxylate exhibits the maximum DR ability about 12% higher than pure CMC solutions (35% and 23% respectively) at a high flow rate. An addition of 100ppm Alfonic 1412-3 Ethoxylate to 500ppm CMC only has a slightly higher %DR than pure CMC solution at the same concentration. In a 1.5 inch pipe, a little addition of Alfonic 1412-3 causes a sharp decrease of %DR in pipeline. The solution consisting of 500ppm CMC and 100ppm Alfonic 1412-3 Ethoxylate shows no DR when flow rate is lower than 0.004m^3/s and only reaches 2% DR at 0.0059m^3/s.

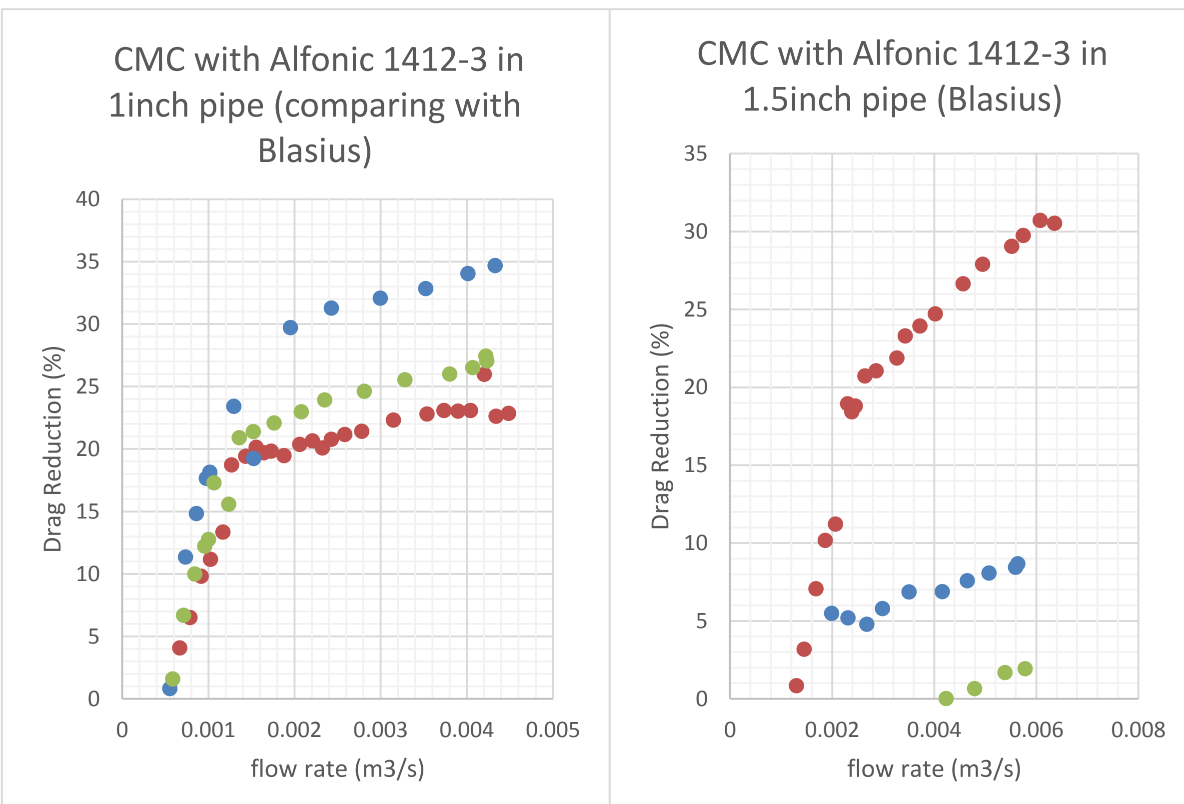


Figure 35 %DR of CMC with Alfonic 1412-3 Ethoxylate (comparing with Blasius Equation)

(• are 500ppm CMC solution, • are 500ppm CMC with 30ppm Alfonic 1412-3 Ethoxylate solution, • are 500ppm CMC with 100ppm Alfonic 1412-3 Ethoxylate solution)

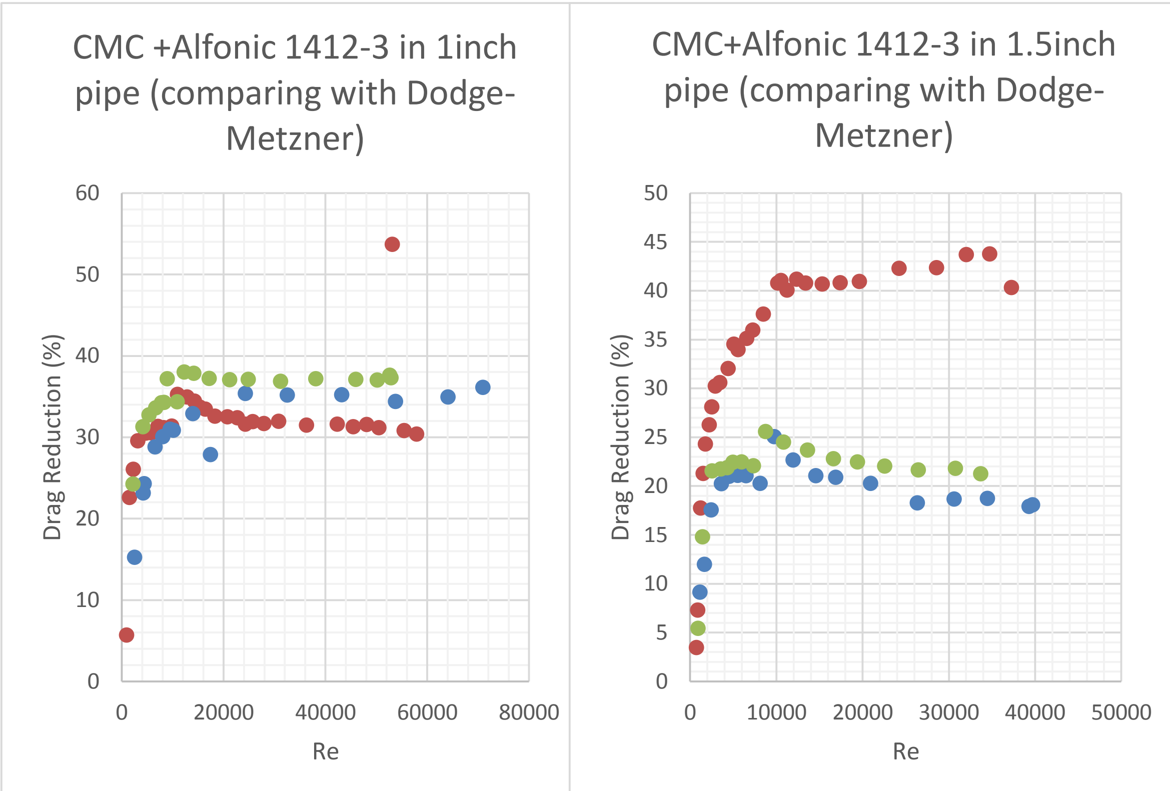


Figure 36 %DR of CMC with Alfonic 1412-3 Ethoxylate (comparing with Dodge-Metzner Equation)

(● are 500ppm CMC solution, ● are 500ppm CMC with 30ppm Alfonic 1412-3 Ethoxylate solution, ● are 500ppm CMC with 100ppm Alfonic 1412-3 Ethoxylate solution)

Figure 36 shows %DR calculated with reference to the Dodge-Metzner Equation. In a 1inch pipe, the addition of surfactant has no significant effect on DR. However, a 50% decrease in %DR is observed in 1.5inch pipe upon the addition of Alfonic to CMC solution; %DR is about 42% for pure CMC solution and about 20% for 500ppm CMC with 30ppm or 100ppm Alfonic concentration. Thus the pipe diameter affects %DR strongly. .

5.2.3 Conclusion

Since Alfonics are non-ionic surfactants and CMC is an anionic polymer, the interactions can only take place via the combination of hydrophobic groups. Fluctuations in DR have been observed in these experiments. The conclusions are as follows, For CMC/Alfonic 1412-9 system,

- Critical micelle concentration is determined by the measurement of surface tension. The differences between pure Alfonic 1412-9 solution and CMC/Alfonic 1412-9 solution on surface tension indicate that interactions occur in the mixed system.
- Taking Blasius Equation as a standard for normal non drag-reducing fluids, the addition of a small amount of surfactant in polymer gives higher DR ability than pure polymer solutions (100ppm Alfonic in 100ppm CMC and 20ppm Alfonic in 500ppm CMC). Upon increasing the surfactant concentration, a reduction in %DR takes place (500ppm Alfonic in 100ppm CMC). The addition of surfactant also causes a change from Type A to Type B [88] drag reduction behavior. The hydrophobic interaction is weak at low surfactant concentrations and the surfactant is able to bind onto the polymer chains. The increase in DR results from the independent sole effects from polymer and surfactant. When surfactant concentration is high, the binding effect of surfactant protects polymer from stretching which leads to the reduction in DR.
- Taking Dodge-Metzner equation as a standard for the normal non drag-reducing non-Newtonian fluid, only solution containing 500ppm CMC exhibits DR ability. 20ppm Alfonic 1412-9 in 500ppm CMC exhibit the same DR as the pure polymer solution in 1inch pipe and a slight decrease in DR in 1.5inch pipe. Thus, the diameter effect is observed in CMC/Alfonic 1412-9 system.
- Although diameter has a negative influence on the interactions between CMC and Alfonic 1412-9, a higher DR is generally observed in a larger diameter pipe. An increase in DR may be due to the availability of larger inner surface areafor the attachment of the aggregates formed by polymer and surfactant.

For CMC/Alfonic 1412-3 system,

- The interaction between CMC and Alfonic 1412-3 is weak such that no obvious changes in critical micelle concentration can be observed by surface tension and conductivity measurements.
- In a 1inch pipeline, solutions exhibit the same behavior as CMC/Alfonic 1412-9 system. 30ppm and 100ppm Alfonic 1412-3 in 500ppm CMC solutions have higher %DR when compared with

Blasius and Dodge-Metzner Equations separately. In a large diameter pipe (1.5inch), a different DR behavior is observed. Adding Alfonic 1412-3 decreases %DR of pure polymer solution significantly, from 30% with no additive to 9% with 30ppm Alfonic 1412-3 and to 2% with 100ppm Alfonic 1412-3 (taking Blasius Equation as standard). The interactions between additives and turbulence structure and flow rheology are responsible for the observed behavior.

5.3 CMC with Aromox DMC

Another surfactant selected in our research is Aromox DMC, the main component of which is dimethylcocalkyamine oxides. Aromox has been tested by several researchers. It can exhibit a high drag reduction ability in pipeline flows (over 70%) [52][89].It has a wide variety of applications as cleansing surfactant, chemical intermediate, foam booster and acid degreaser both in industry and in our daily lives.

5.3.1 Bench-scale Results

Properties such as surface tension, conductivity and shear viscosity were measured in the bench-scale experiments. **Figure 37** shows the change of surface tension with the increase of Aromox DMC concentration in 500ppm CMC solutions. The surface tension of solutions starts at 66 dyne/cm with no Aromox and decreases to 37 dyne/cm when surfactant concentration was 150ppm and reached the lowest point around 32 dyne/cm at 500ppm Aromox DMC concentration. From the plot two points should be noted. The first one is when surfactant concentration is 30ppm where the slope of surface tension plot reduces sharply. We expect that aggregation between polymer and surfactant begins at this surfactant concentration.. After this point, the surface tension decreases gradually until 150ppm surfactant concentration is reached. From this point on, surface tension remains almost constant. It seems that at 500ppm CMC concentration, 150ppm Aromox concentration is the polymer saturation point (PSP). . At higher surfactant concentrations, free micelles are formed.

Regarding conductivity, it fluctuates slightly and ranges from 0.53μs/cm to 0.57μs/cm (see **Figure 38**). Two critical points observed in surface tension plot are also observed here.. At 30ppm, a mild decrease in conductivity occurs. When surfactant concentration reaches 150ppm, the conductivity begins to rise slowly. **Figure 39** presents the relationship about shear viscosity versus shear rate. All fluids exhibit shear-thinning behavior although it is difficult to identify the influence of surfactant on polymer-surfactant mixture viscosity.

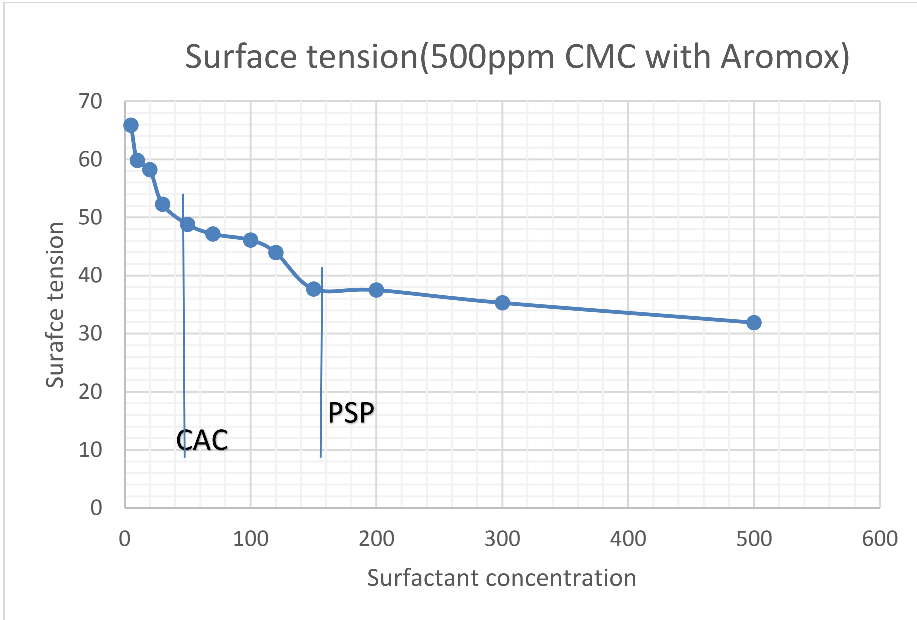


Figure 37 Surface Tension of 500ppm CMC with Aromox DMC

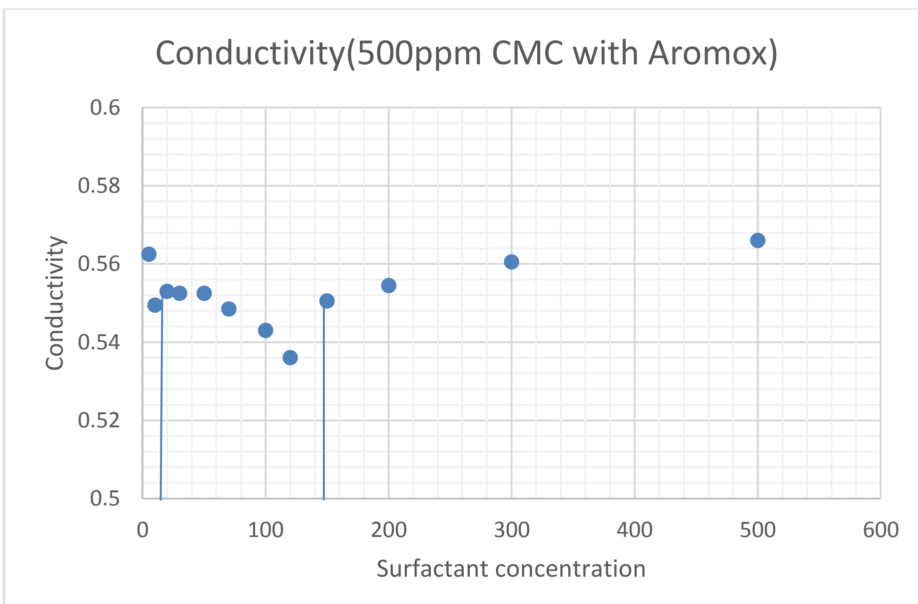


Figure 38 Conductivity of 500ppm CMC with Aromox DMC

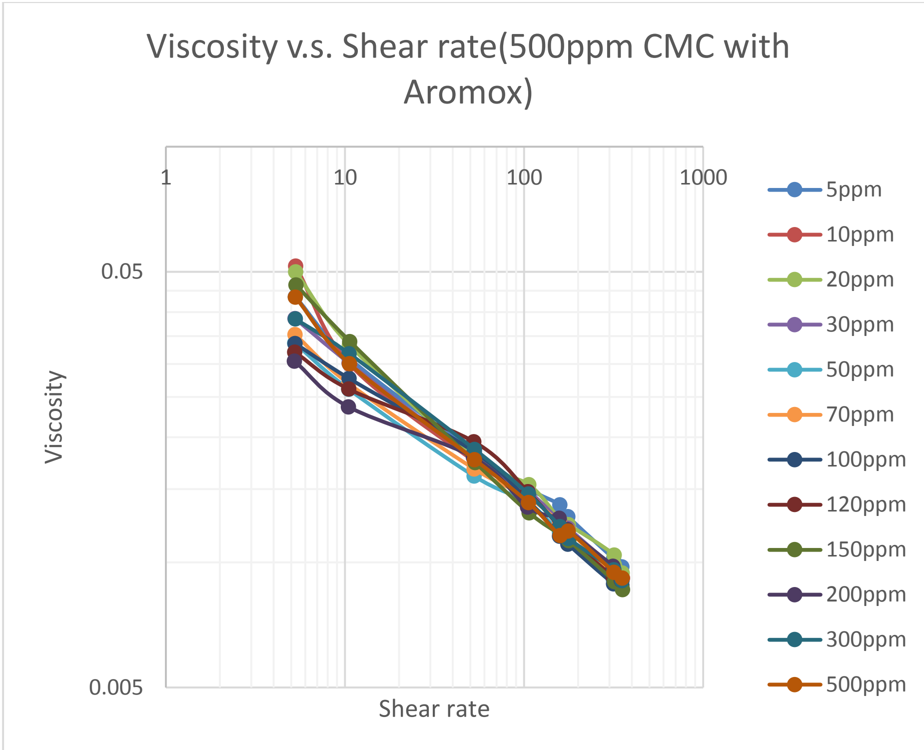


Figure 39 Viscosity versus Shear Rate (500ppm CMC + Aromox DMC)

5.3.2 Pipeline Results

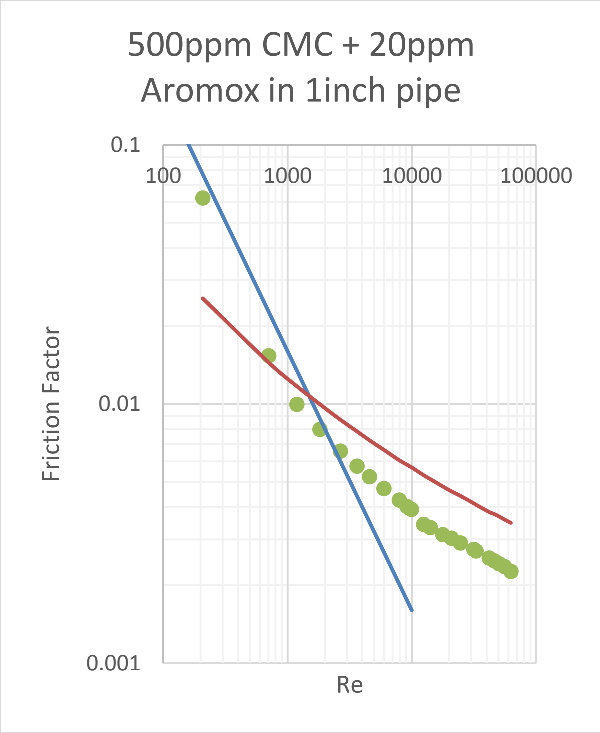


Figure 40 (a)

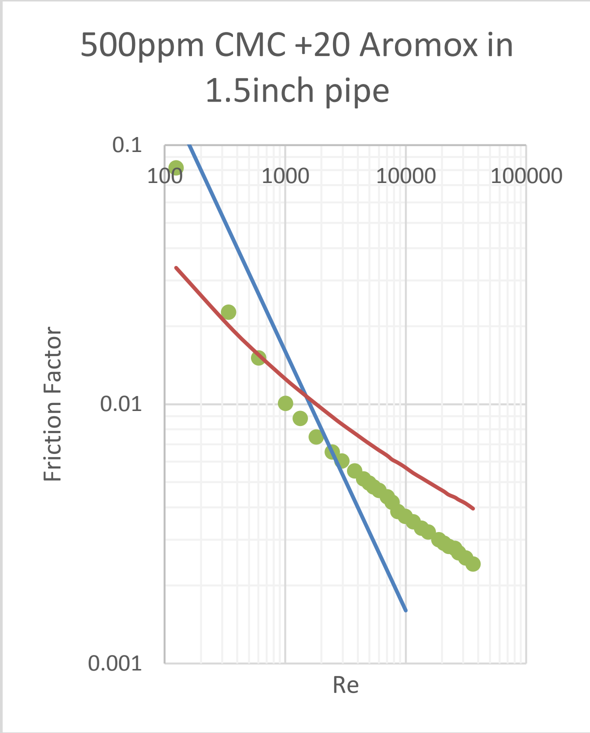


Figure 40 (b)

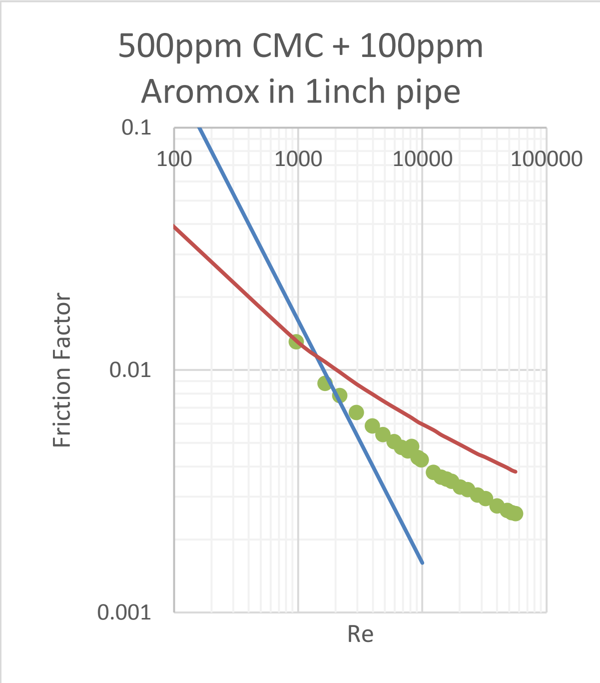


Figure 40 (c)

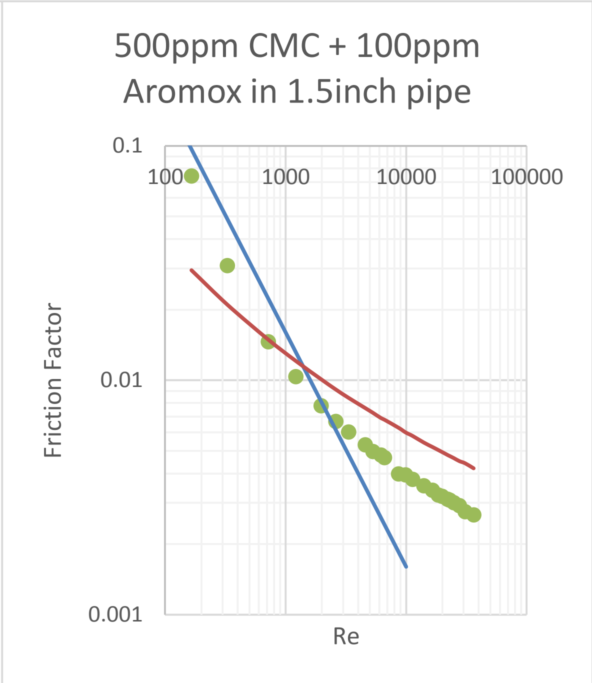


Figure 40 (d)

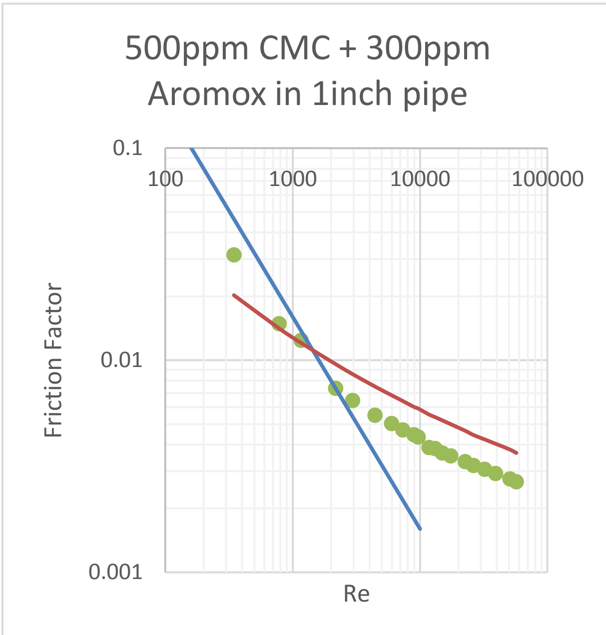


Figure 40 (e)

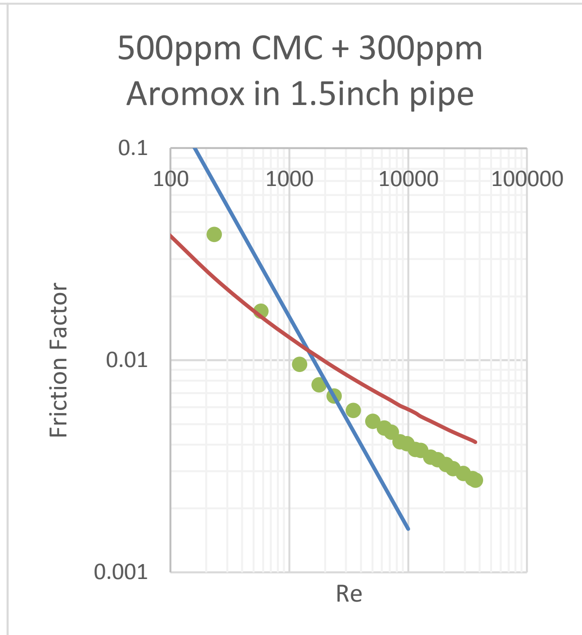


Figure 40 (f)

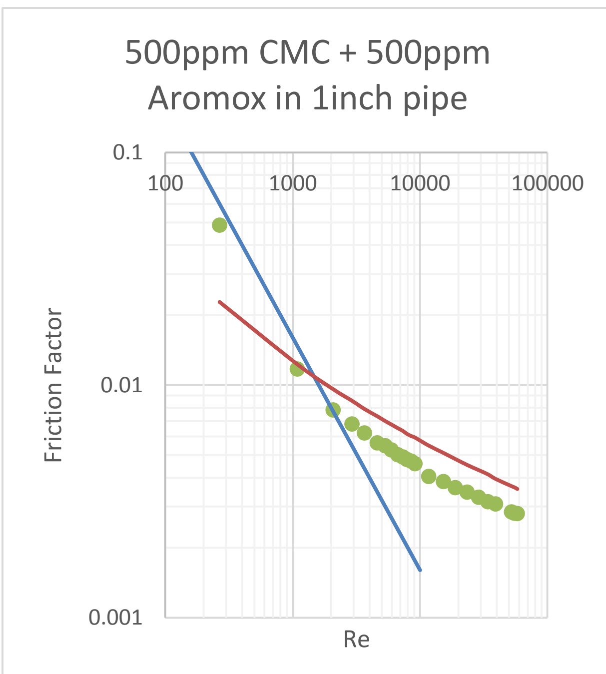


Figure 40 (g)

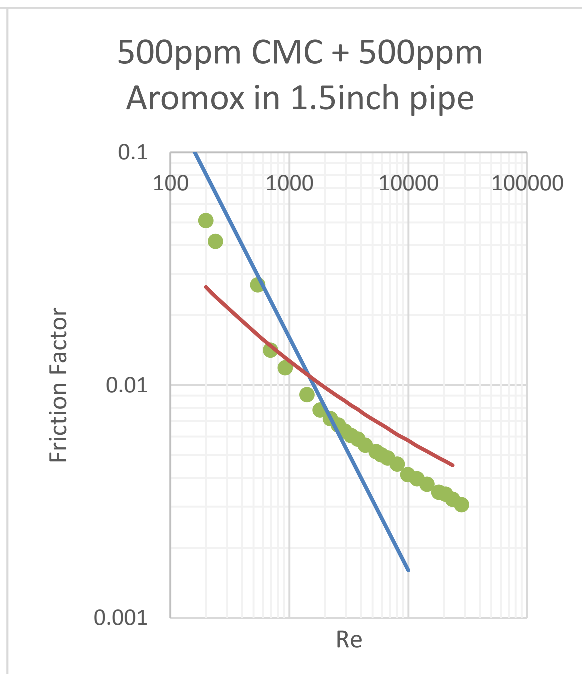


Figure 40 (h)

Figure 40 CMC + Aromox DMC Pipeline Behavior

(is Laminar Flow, is Dodge-Metzner Equation, are flow data)

Figure 40 (a) to (h) illustrated the flow curve of 500ppm CMC with different concentration of Aromox DMC in 1inch and 1.5inch pipes specifically. In this section, 20ppm, 100ppm, 300ppm and 500ppm Aromox concentrations are tested in order to find out the effect of surfactant concentration. %DR are figured out by comparing with Blasius and Dodge-Metzner Equation separately, and the results are shown below (**Figure 41** and **Figure 42**).

Interestingly, when comparing with water flow at the same flow rate, an addition of 500ppm Aromox DMC in pure CMC solutions promotes %DR substancially on a large margin reaching 45% in 1inch and 50% in 1.5inch pipe. While low Aromox concentrations (20ppm, 100ppm and 300ppm) don not have such high DR abilities and even produce negative effects in 1.5 inch pipe. At high flow rate %DR, generally, 500ppm CMC with Aromox DMC solutions have 20-30% DR ability approximately. Taking Dodge-Metzner Equation as datum equation, the results are illustrated in Figure 35. In this section, pure polymer solutions have relative higher DR abilities. With the increase of surfactant concentration, the percentage of DR goes down, bottoming at 22% with 500ppm Aromox DMC in 1.5 inch. Pure CMC solution has almost the highest drag reduction ability, which is 32% in 1inch pipe and 43% in 1.5 inch pipe.

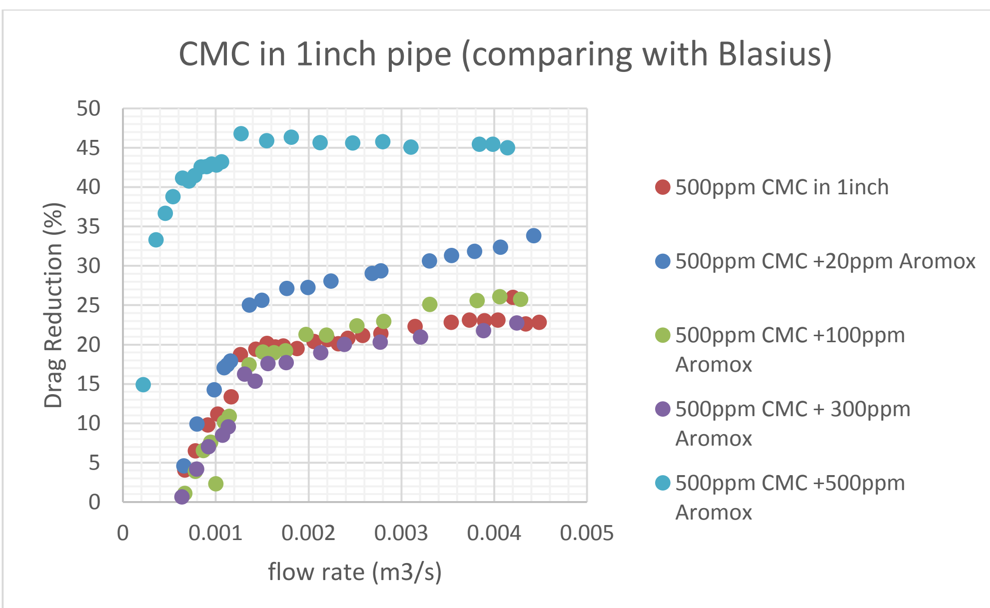


Figure 41 (a)

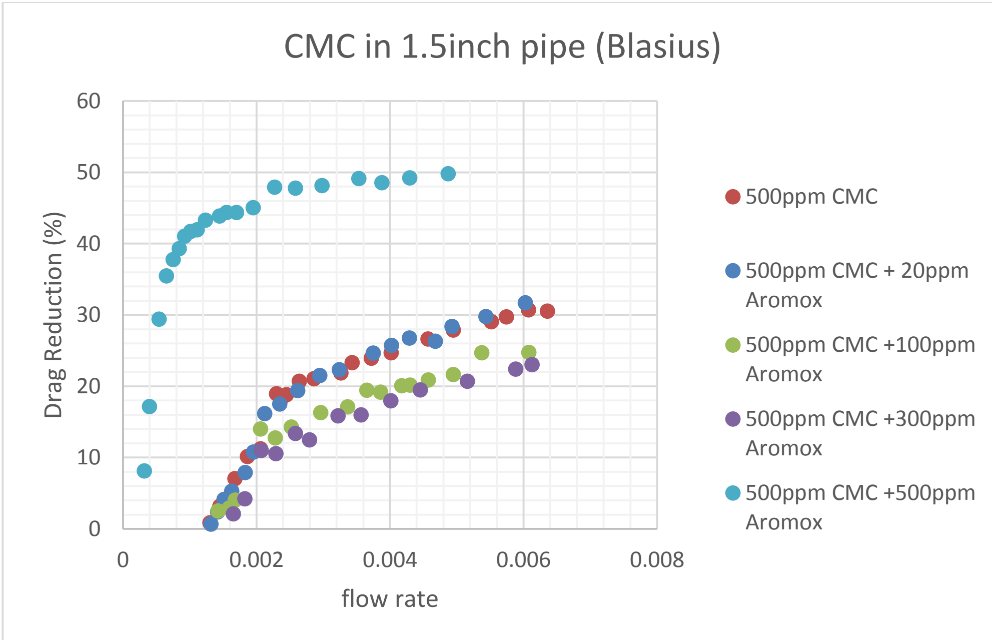


Figure 41 (b)

Figure 41 %DR of CMC with Aromox (comparing with Blasius Equation)

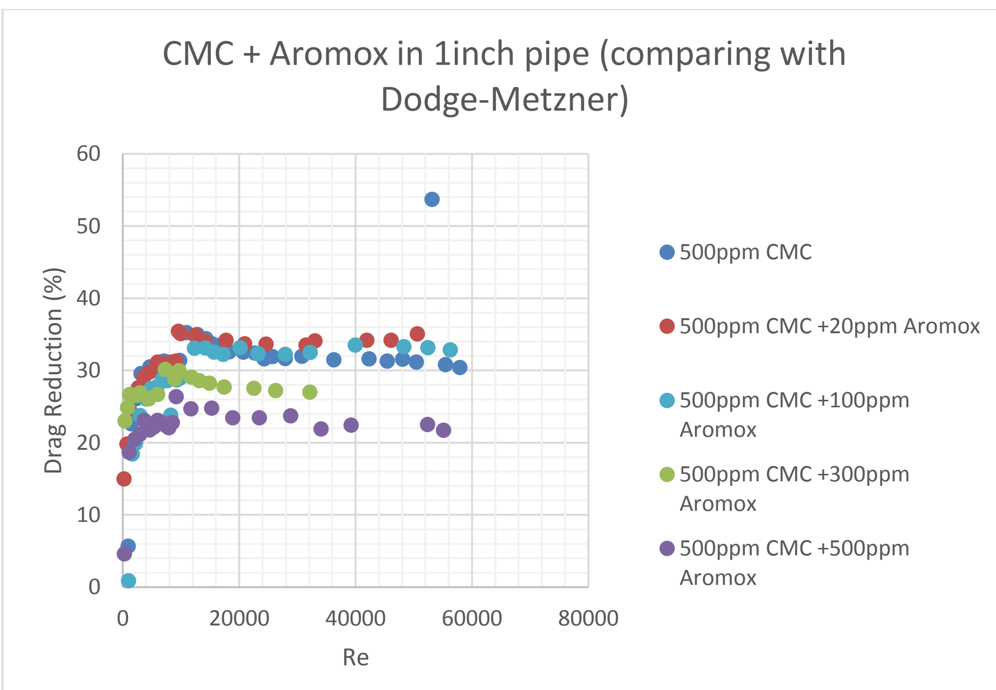


Figure 42 (a)

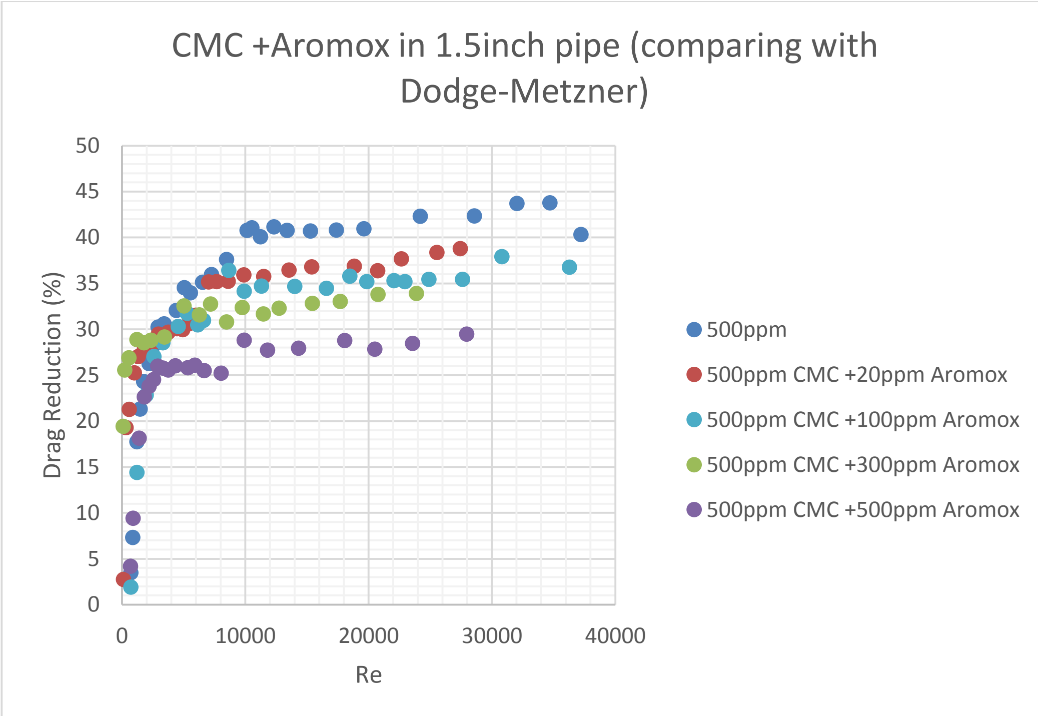


Figure 42 (b)

Figure 42 %DR of CMC with Aromox (comparing with Dodge-Metzner Equation)

5.3.3 Conclusion

- CAC and PSP points are estimated by surface tension measurement. The results of conductivity further confirm the existence of interactions between CMC and Aromox (In 500ppm CMC solutions, CAC=30ppm Aromox, PSP=150ppm Aromox).
- Shear viscosity versus shear rate plots illustrate no valuable statement about the interactions.
- Compared with Newtonian fluid (Blasius Equation), 20ppm Aromox in 500ppm CMC solution exhibit slight higher %DR, which is because 20ppm is lower than CAC, no association is formed. The free micelle of surfactant have the ability to promote drag reduction. Keeping increasing the surfactant concentration, %DR decrease when surfactants are binding onto the backbone of polymer, this aggregation process affects the DR ability of polymer. 300ppm Aromox almost have the same %DR with 100ppm Aromox though 300ppm has exceeded PSP. This is maybe because both free micelles and polymer-surfactant aggregation exist in the solution. When

surfactant concentration reaches 500ppm, remarkable promotion can be reflected by the increase of %DR (approximately 30%). This fact further confirms free Aromox have excellent drag-reducing ability in aqueous solutions. Besides, free Aromox micelles have positive effect on the onset of DR, which is shown in both pipes.

- While considering Dodge-Metzner Curve, totally different results are presented (**Figure 42**). Pure 500ppm CMC solution have the highest %DR, adding Aromox in polymer solutions will result in deductions in DR ability.
- Diameter effect is found to be insignificant in CMC/Aromox system

5.4 CMC with Stepanol WA-100 NF/USP and Stepwet DF-95

Both Stepanol WA-100 NF/USP and Stepwet DF-95 are high active anionic surfactants, the main component of them are sodium lauryl sulfates (SLS) with different composition. SLS has been widely tested on its drag reduction [90][91] in aqueous and oil flow and found nearly 30% DR could be achieved by little amount of SLS concentration. Both of them have a wide variety of applications in industry and personal cares, such as dry products, oil dispersants, suspension concentrates, bar shop and body wash. Also, after extensive researches, Stepanol WA-100 has been discovered to have readily biodegradable properties. CMC also has anionic ion, due to the opposite charges in polymers and surfactants, they can only interact in hydrophobic groups.

5.4.1 CMC with Stepanol WA-100 NF/USP

5.4.1.1 Bench Scale Results

Figure 43 presents the surface tension trend of 100ppm and 500ppm CMC with the increase of Stepanol concentrations. Obviously, 500ppm CMC solution with Stepanol has a sharper decreasing slope when surfactant concentration is higher than 200ppm and the surface tension of it remains around 33 dyne/cm after 700ppm Stepanol concentration which is slightly lower than that of 100ppm CMC with the same Surfactant concentration (34 dyne/cm).

As for conductivity (see **Figure 44**), the starting points are determined by polymer concentration, with the increase of surfactant concentration, both of the two lines go up remarkably at the same slope, this is due to the negative electricity of Stepanol WA-100 NF/USP. While, no change in increasing slope can be discovered at such a low surfactant concentration, higher surfactant concentration should be tested to find critical micelle concentration.

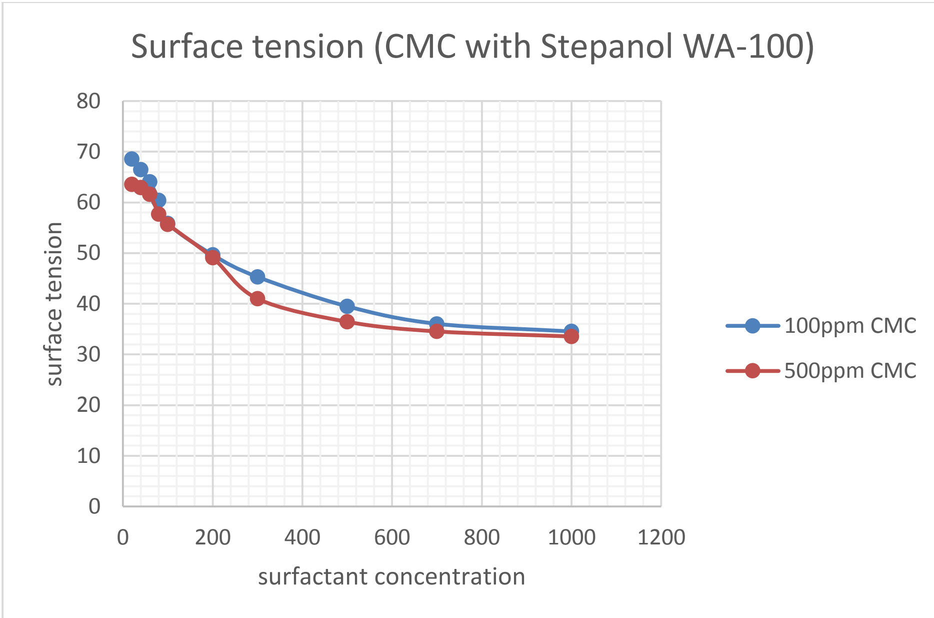


Figure 43 Surface Tension of CMC with Stepanol WA-100

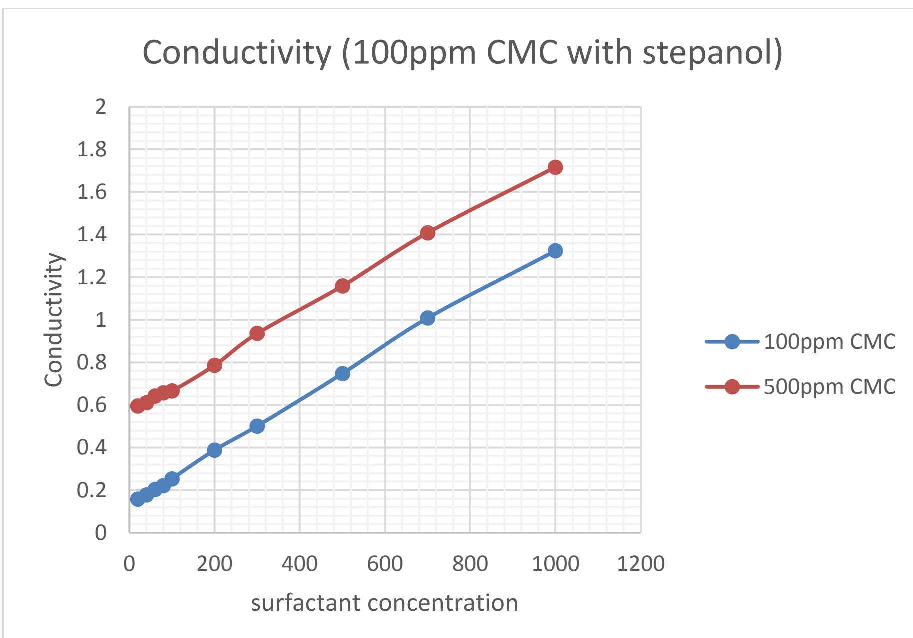


Figure 44 Conductivity of CMC with Stepanol WA-100

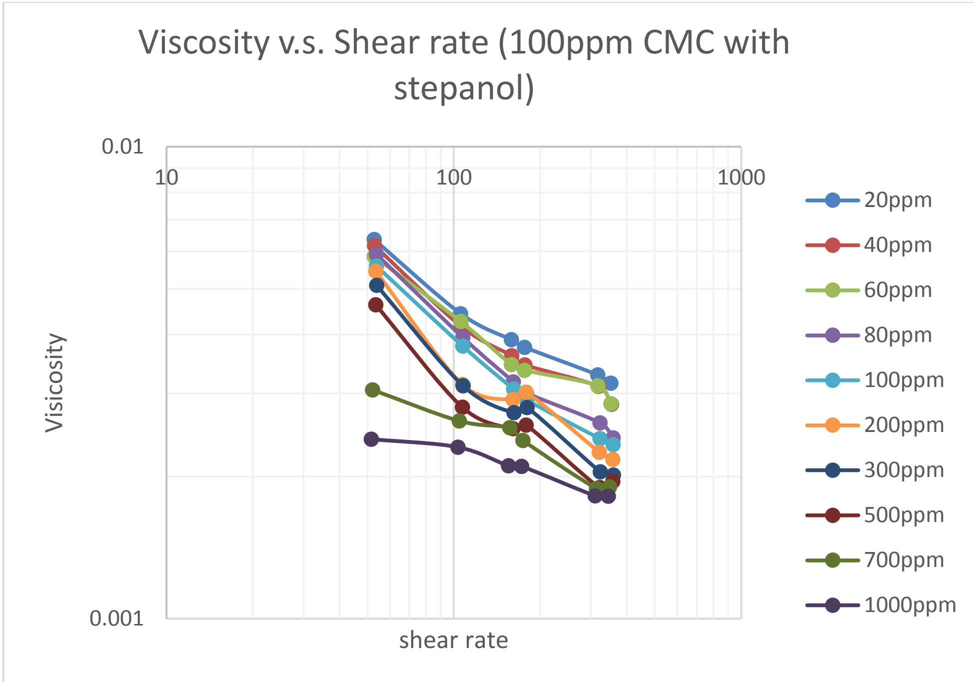


Figure 45 (a)

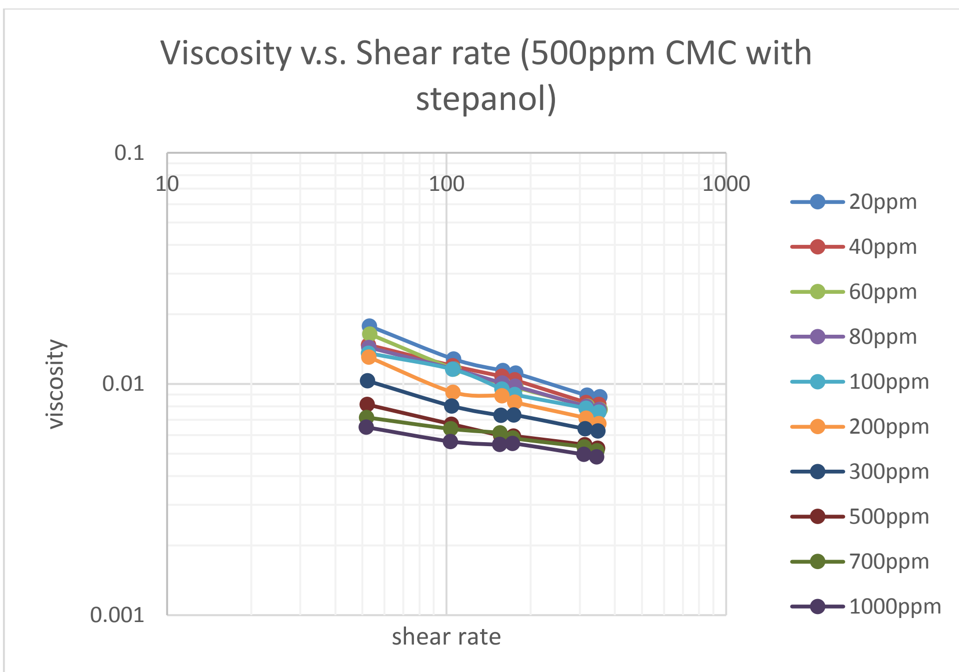


Figure 45 (b)

Figure 45 Shear Viscosity versus Shear Rate (CMC with Stepanol WA-100)

Shear viscosity of prepared solution were also tested and the relationships between it and shear rate are illustrated in **Figure 45** grouped by polymer concentration. Clearly, from the top line to the bottom line, the concentrations of surfactant are rising readily which is shown on both (a) and (b). The clear differences between every solution were significant in logarithmic scale. From which, we estimate that, there should be some interactions between CMC and Stepanol WA-100. The results of whether these interactions would have a positive effect on DR ability will be shown in the next part.

5.4.1.2 Pipeline Results

The pipeline behavior of 500ppm CMC with 100ppm and 300ppm Stepanol WA-100 NF/USP in both 1inch and 1.5 inch are listed in **Figure 46** (a) to (d). Comparing with Dodge-Metzner Equation, significant DR can be found by graphs directly, while the comparison with Newtonian flow (Blasius Equation) is required to be calculated. The real %DR are presented by **Figure 47** and **Figure 48**.

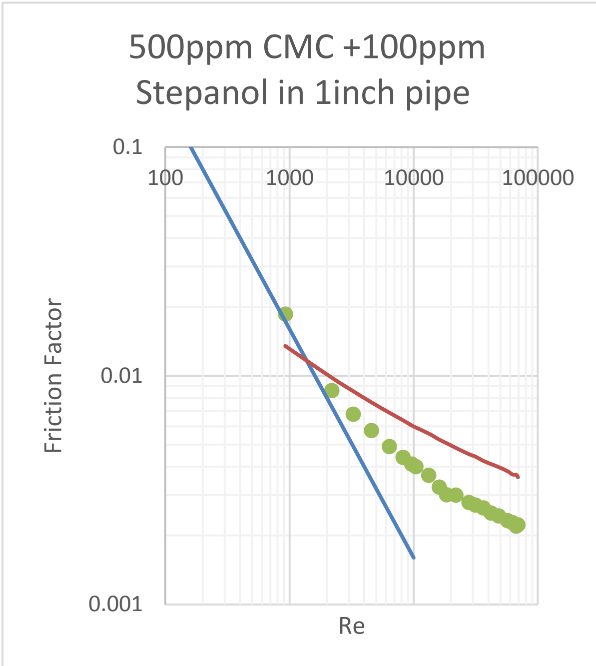


Figure 46 (a)

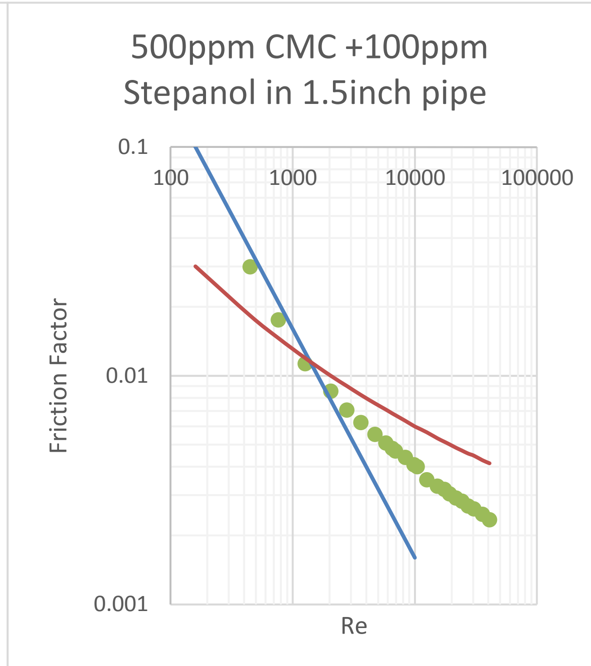


Figure 46 (b)

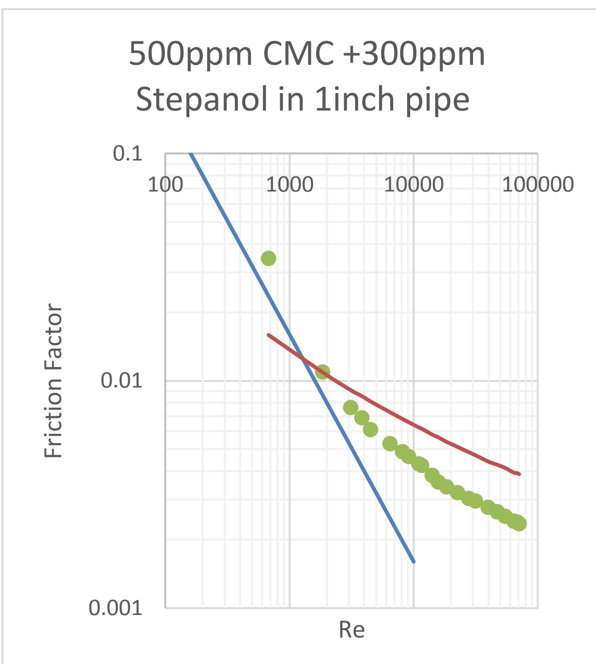


Figure 46 (c)

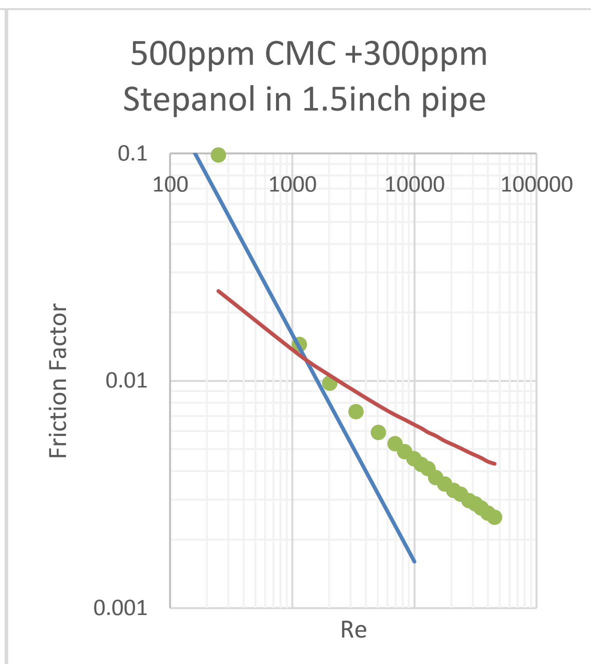


Figure 46 (d)

Figure 46 CMC + Stepanol WA-100 Pipeline Behavior

(—— is Laminar Flow, —— is Dodge-Metzner Equation, ● are flow data)

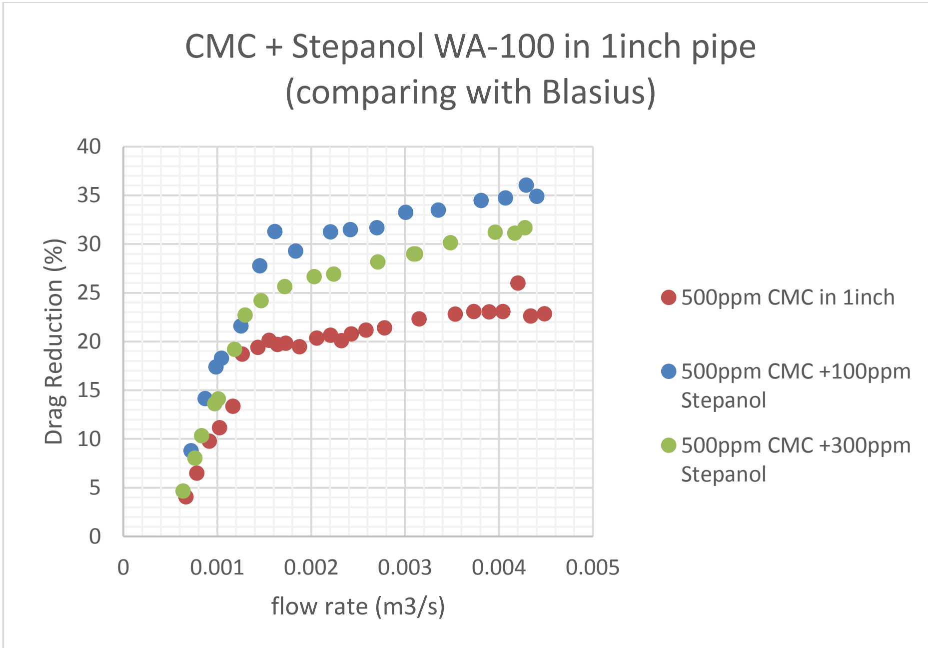


Figure 47 (a)

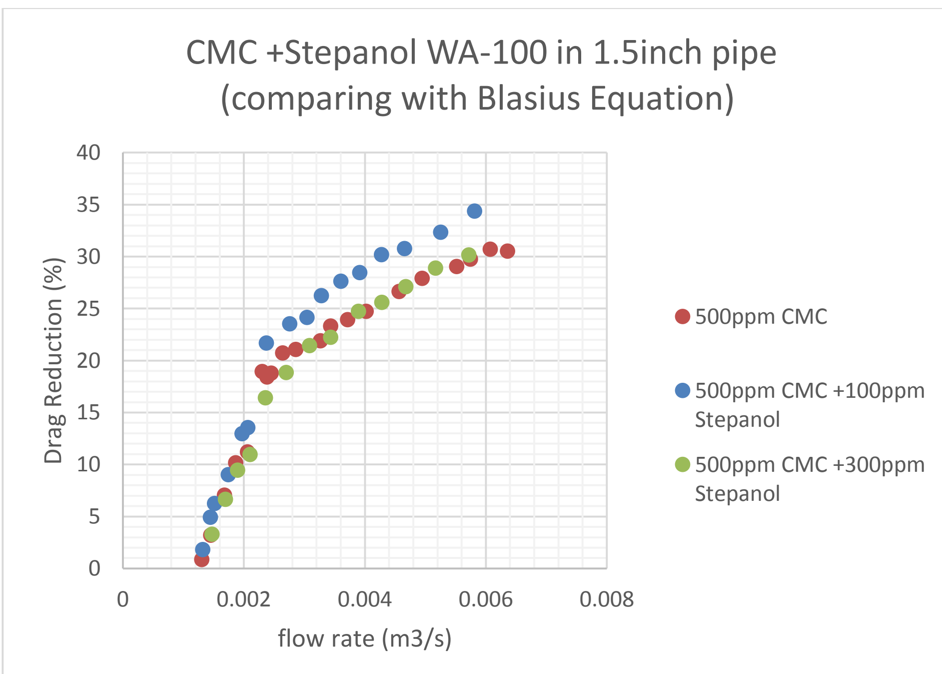


Figure 47 (b)

Figure 47 %DR of CMC with Stepanol WA-100 (comparing with Blasius Equation)

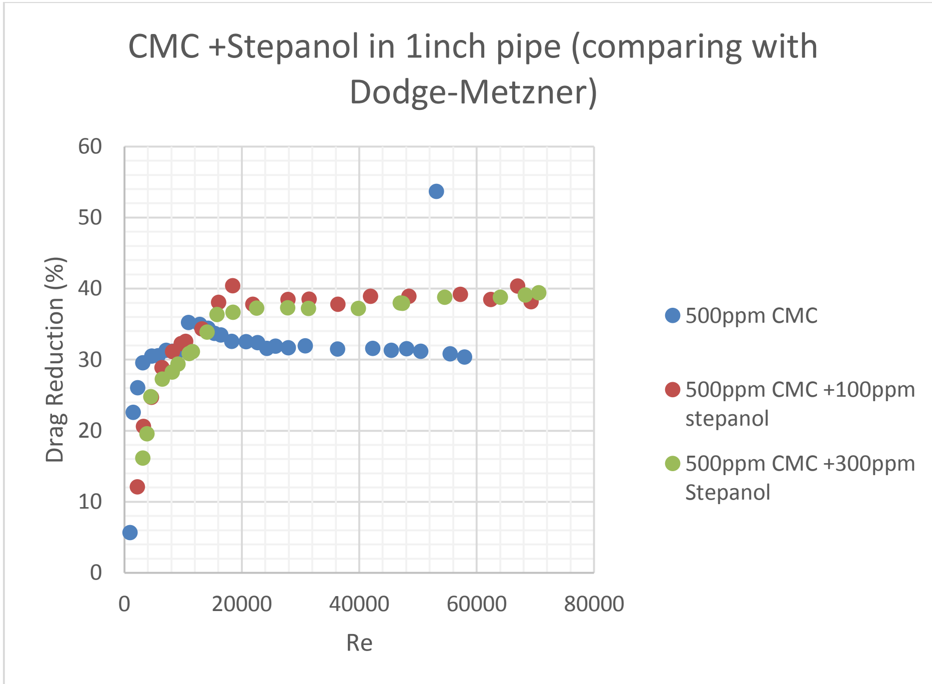


Figure 48(a)

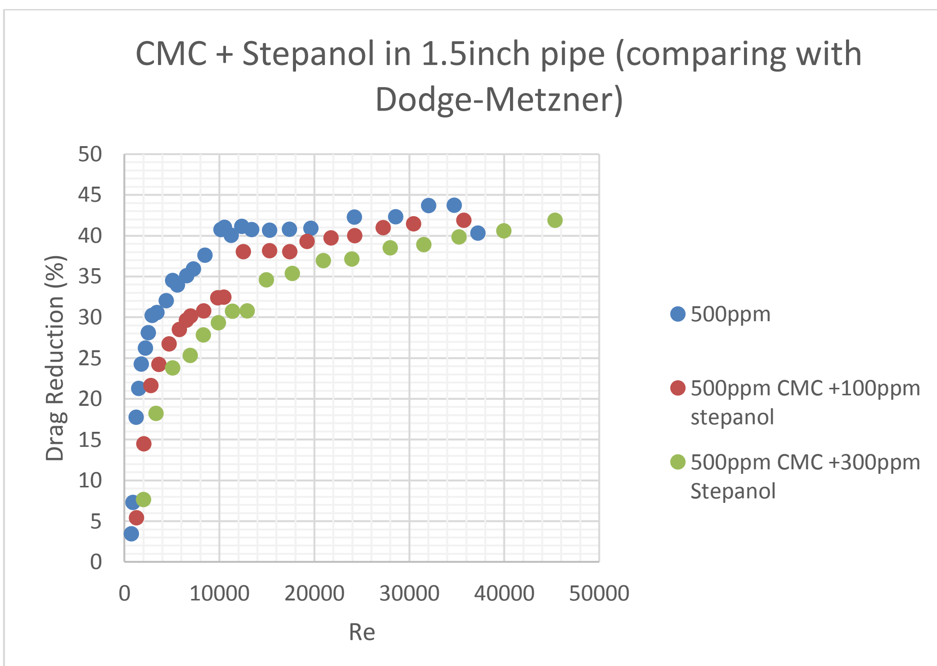


Figure 48 (b)

Figure 48 %DR of CMC with Stepanol WA-100 (comparing with Dodge-Metzenr Equation)

The DR percentage have been calculated and the results comparing with Blasius Equation and Dodge-Metzner Equaiton are listed on **Figure 47** and **Figure 48**. From **Figure 47** (comparing with Blasius Equation), it is clear that 500ppm CMC with 100ppm Stepanol has a relative higher %DR, reaching 35% at high flow rate in both pipes. In 1.5inch pipe, the second comes 500ppm CMC with 300ppm Stepanol WA-100 solutions (32%) which is 9% higher than that of pure CMC solution. While, in 1.5 inch pipe, the other two solutions remain the same level in %DR, ending in 35% when flow rate is 0.006m^3/s. Comparing with Dodge-Metzner Equation, 500ppm CMC with 100ppm and 300ppm Stepanol WA-100 solutions produce close DR abilities which are 40% approximately in both pipes. However, the %DR of pure 500ppm CMC in 1inch is only a little bit higher than 30% in 1inch pipe.

5.4.2 CMC with Stepwet DF-95

5.4.2.1 Bench-scale Results

The solution consists of CMC and Stepwet DF-95 exhibits similar properties as CMC/Stepanol WA-100 solutions. Considering surface tension, both lines got started at 69 dyne/cm with no surfactant and end at 33 dyne/cm with addition of 1000ppm Stepwet DF-95. While in the middle, the solution contains higher CMC concentration presents lower surface tensions at the same surfactant concentration.

As to conductivity, several concentrations of surfactant were measured and it is believed that negative electricity in surfactant makes it increase significantly with the increase of Stepwet concentration. Same as CMC/Stepanol system, the clear and orderly distinctions between different concentrations in shear viscosity versus shear rate graphs are thought due to the intensive interactions between polymer and surfactant (**Figure 51**).

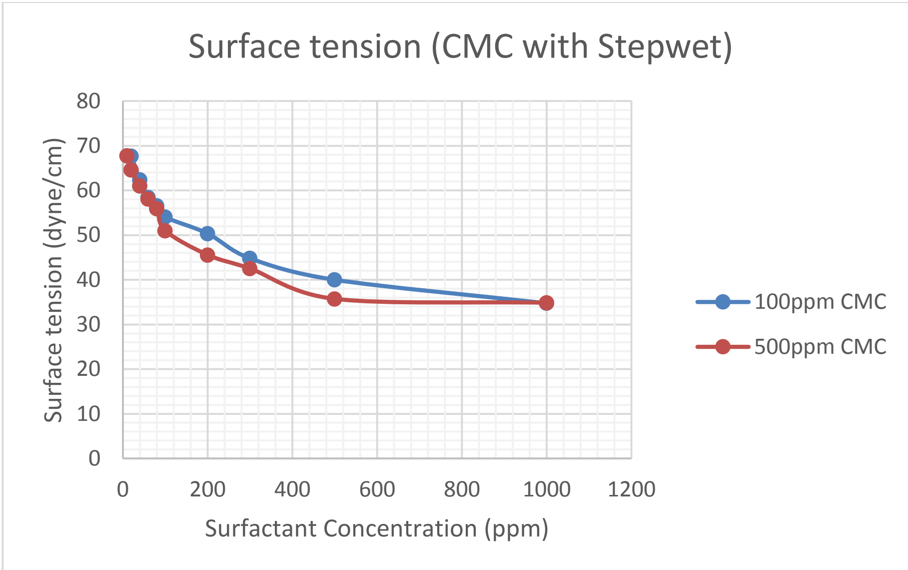


Figure 49 Surface Tension of CMC with Stepwet DF-95

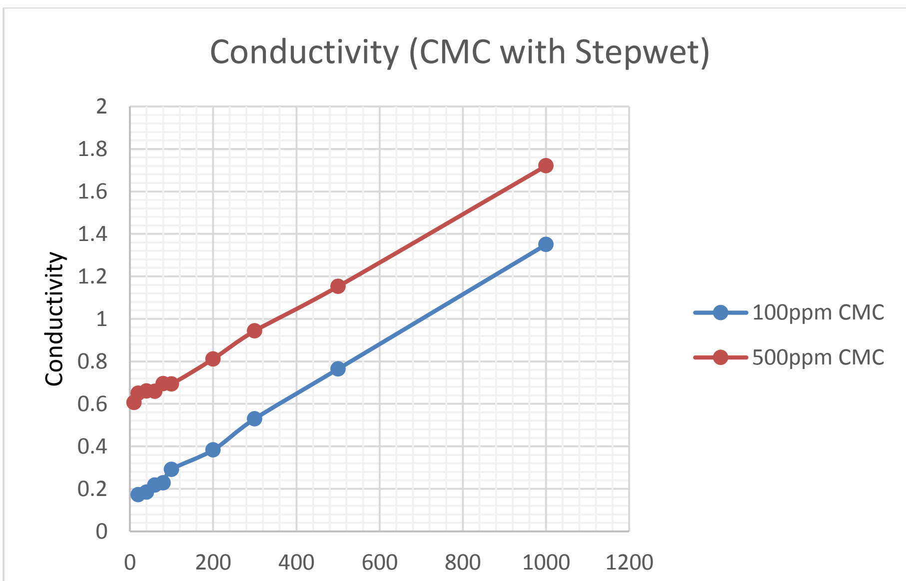


Figure 50 Conductivity of CMC with Stepwet DF-95

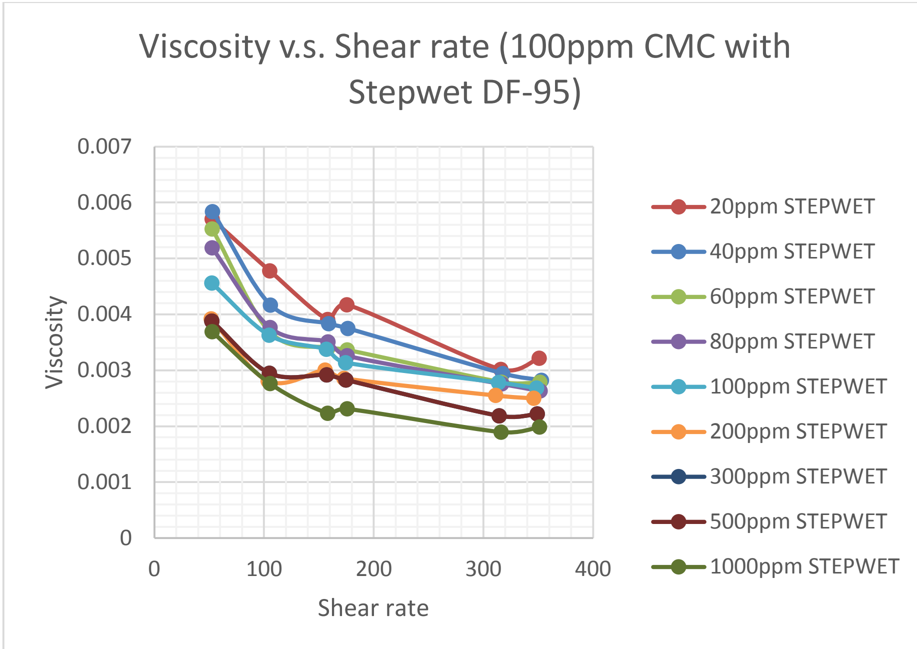


Figure 51 (a)

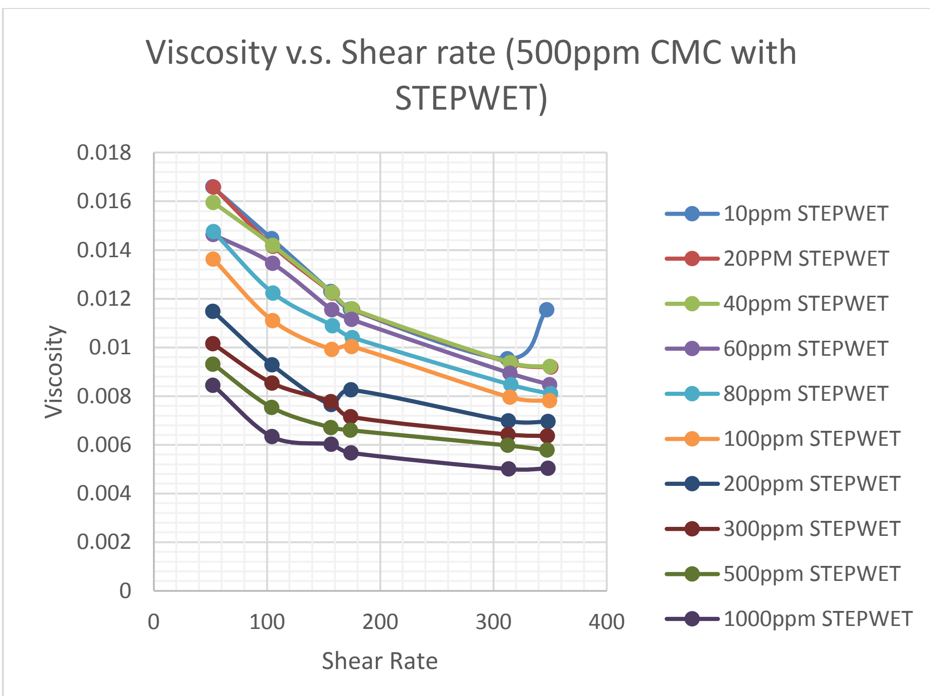


Figure 51 (b)

Figure 51 Shear Viscosity versus Shear Rate (CMC with Stepwet DF-95)

5.4.2.2 Pipeline Results

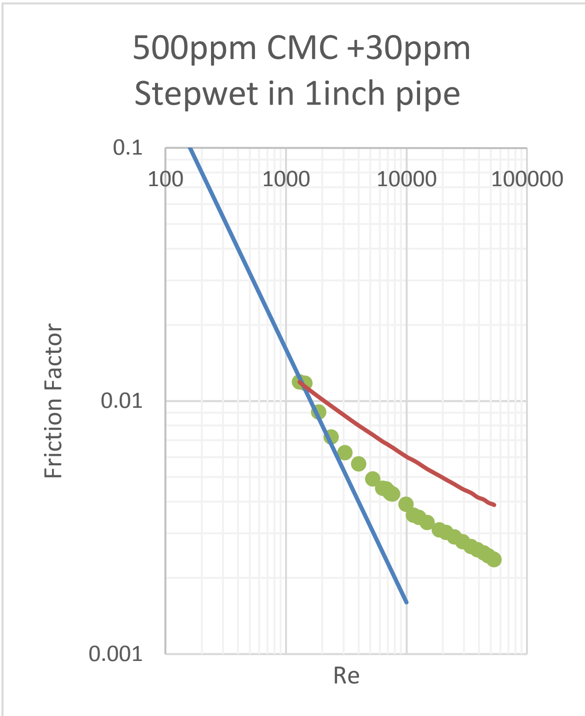


Figure 52 (a)

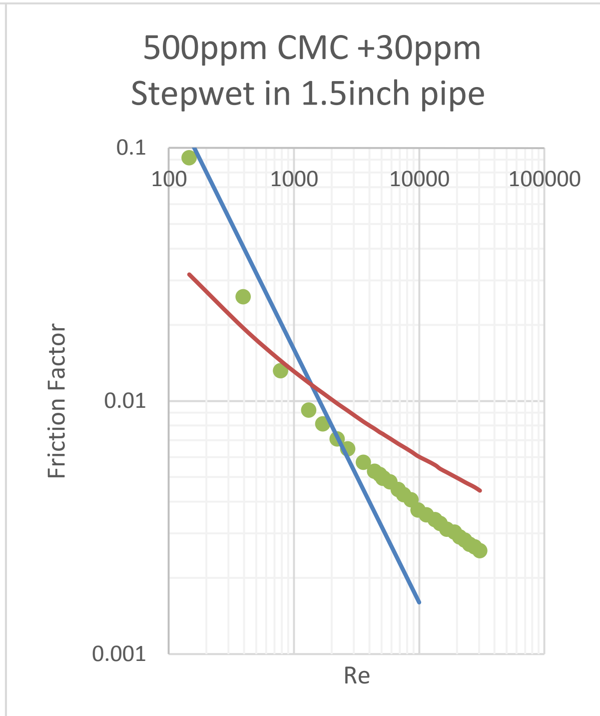


Figure 52 (b)

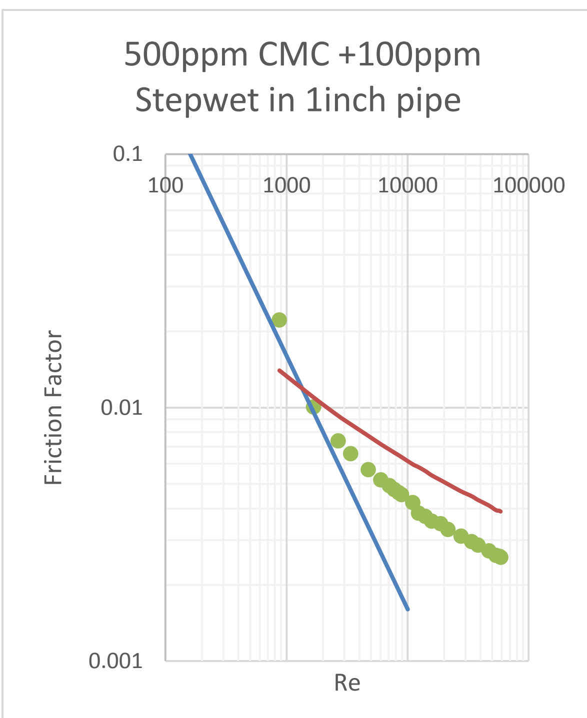


Figure 52 (c)

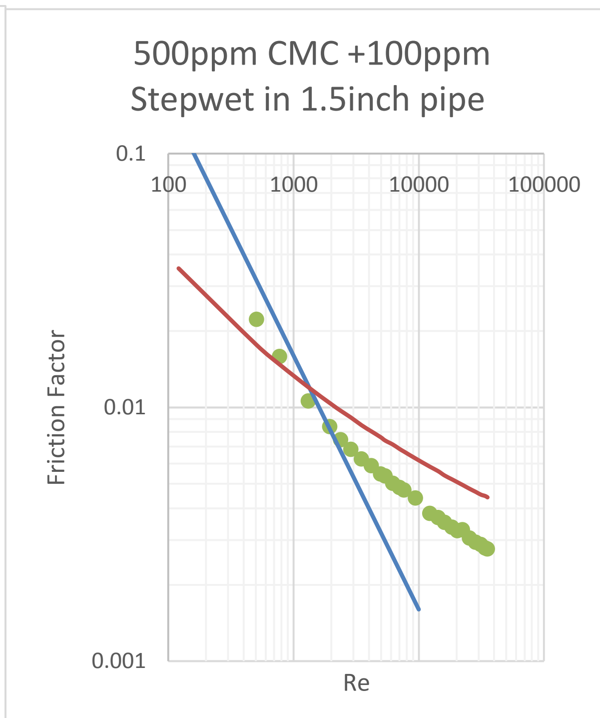


Figure 52 (d)

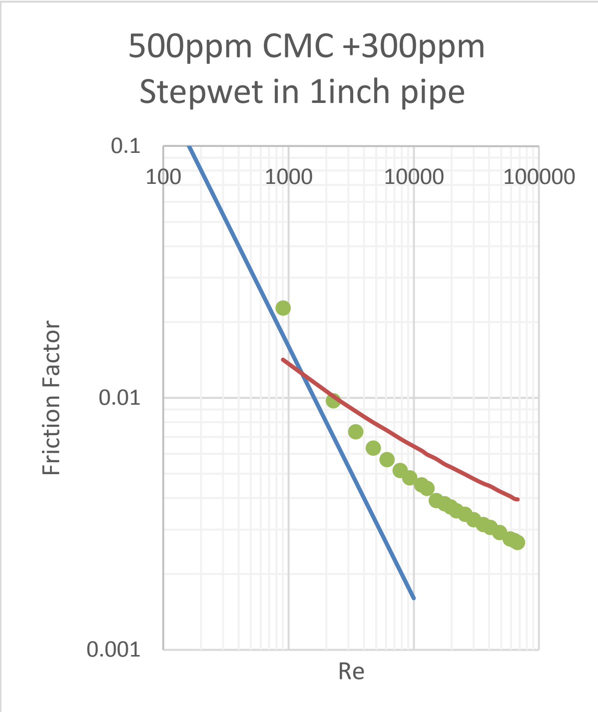


Figure 52 (e)

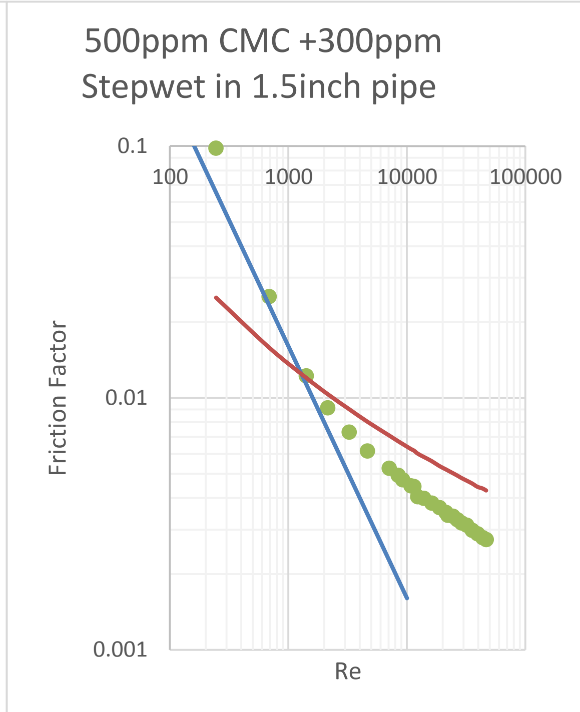


Figure 52 (f)

Figure 52 CMC with Stepwet DF-95 Pipeline Behavior

(is Laminar Flow, is Dodge-Metzner Equation, are flow data)

From these six graphs of **Figure 52**, 500ppm CMC with 30ppm, 100ppm and 300ppm Stepwet DF-95 solutions were prepared and tested. The onset of DR get start at very low Reynolds number and %DR go up with the increase of flow rate. The exact %DR compared with Blasius Equation and Dodge-Metzner Equation are shown in **Figure 53** and **Figure 54** specifically.

According to **Figure 53**, in 1 inch pipe, an addition of 30ppm Stepwet DF-95 to 500ppm CMC solution contributes to a 32.5% DR ability which is almost 10% than that of pure CMC solution. While in 1.5 inch pipe, 500ppm CMC with 30ppm Stepwet DF-95 has the same DR ability as pure 500ppm CMC solution in pipes. With the increase of surfactant concentration, the DR ability decreases and ends at 23% in 1.5inch with 300ppm Stepwet DF-95 concentration when comparing with the friction factor of water flow at the same flow rate. When compared with Non-Newtonian fluid (see **Figure 54**), it behaved the same trend as that with Blaisus Equation except the average %DR are 10% higher approximately.

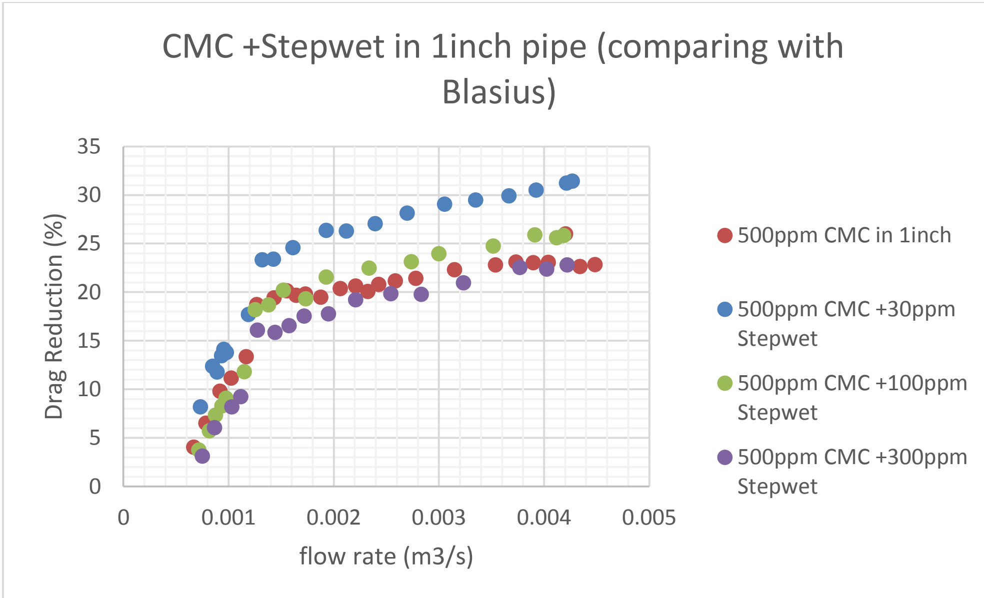


Figure 53 (a)

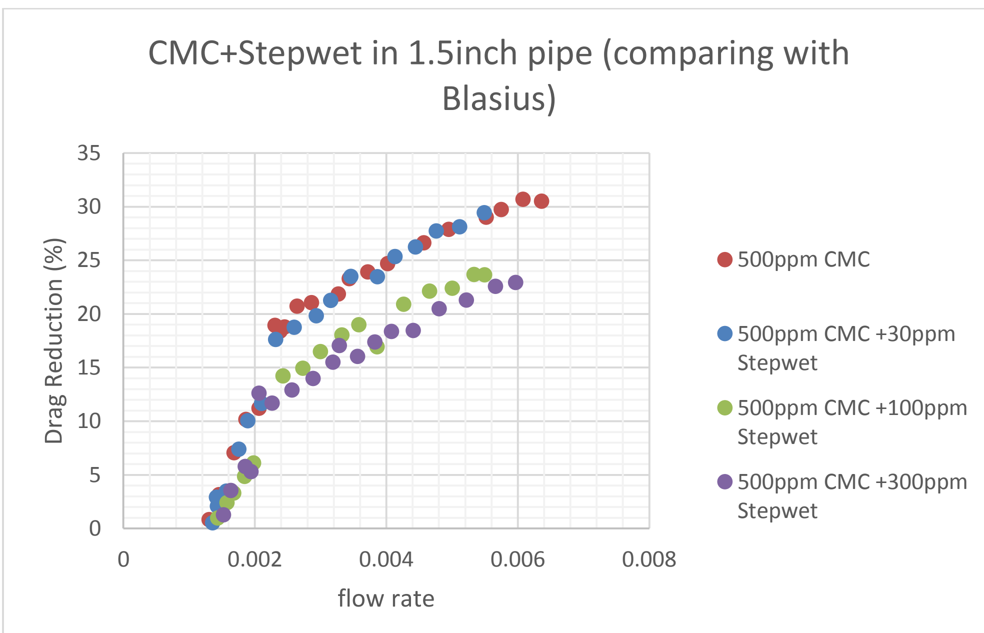


Figure 53 (b)

Figure 53 %DR of CMC with Stepwet DF-95 (comparing with Blasius Equation)

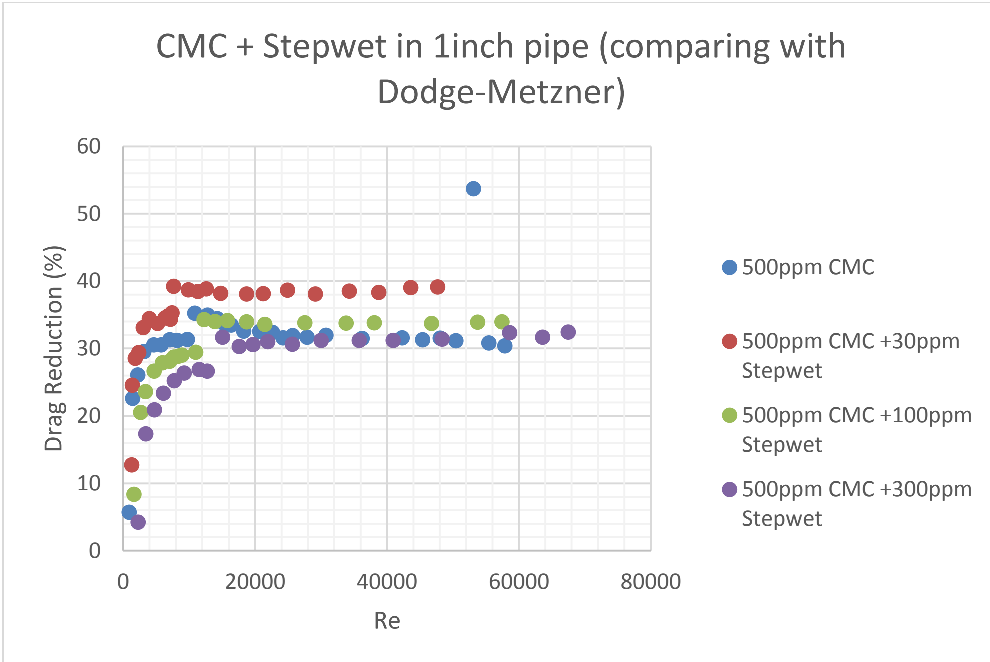


Figure 54 (a)

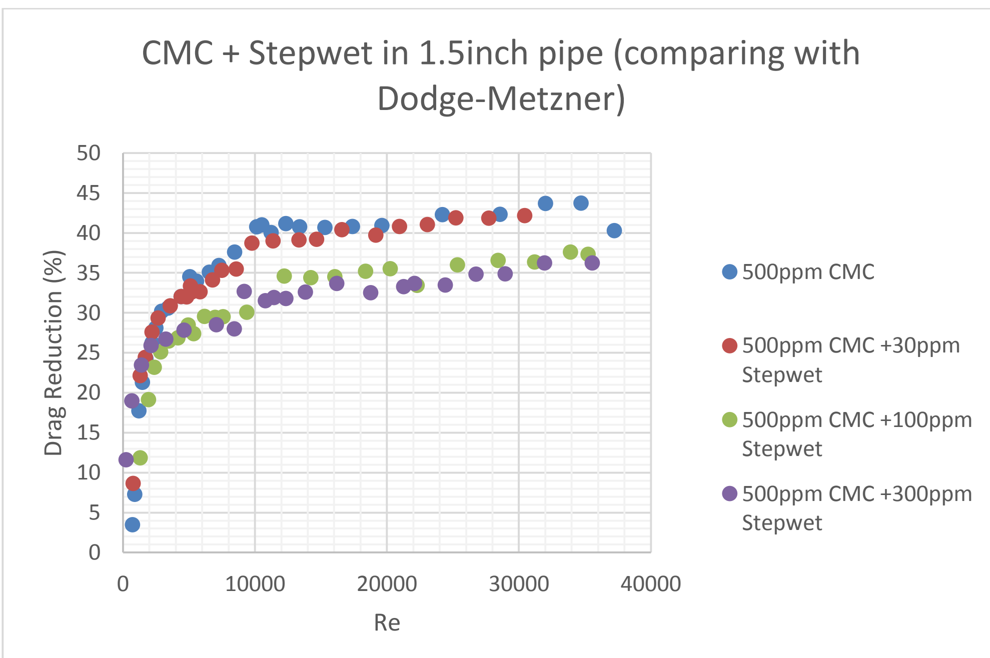


Figure 54 (b)

Figure 54 %DR of CMC with Stepwet DF-95 (comparing with Dodge-Metzner Equation)

5.4.3 Conclusion

Since Stepanol and Stepwet have the same main component with only differences of composition, the conclusions are similar for both of them.

- CMC is not surface-active chemicals and the increase of CMC concentration will not change surface tension values. While with the presence of Stepanol and Stepwet, 500ppm CMC can produce a slightly lower surface tension which is thought to be caused by the interactions between CMC and sodium lauryl sulfates (SLS)
- Obvious distinctions in shear viscosity versus shear rate plots further indicate the existence of interactions. The addition of surfactant into polymer solutions can causes changes in test fluid properties.
- It is supposed that CMC/Stepanol or CMC/Stepwet systems have similar interaction mechanism with CMC/Alfonic systems. Both Alfonic and Stepanol/Stepwet have DR abilities in aqueous solutions alone. While the ion charges in Stepanol/Stepwet system make it more difficult to access to polymer backbone via hydrophobic interaction so that at higher Stepanol/Stepwet concentrations, the solutions can produce %DR higher than pure CMC solutions. Finally, when surfactant concentration is sufficient, a decrease in DR can be observed due to the binding of surfactant onto polymers.
- Diameter effect is also important in CMC/Stepwet system. Taking Blasius or Dodge-Metzner Equation as standard, the data indicate opposite conclusion in %DR, further discussions and experiments are required to confirm.

5.5 CMC with Amphosol CG

Amphosol is a mild zwitterionic surfactant consisting of cocamidopropyl betaines group. It can be used as foam booster, surface cleaning and viscosity builder in many personal care applications. Also, the components of Amphosol have been tested for ready biodegradability to CO_2, H_2O, inorganic salts and biomass with no recalcitrant metabolites formed, which is very eco-friendly for avoiding environmental issues. It this part, combinations of CMC with Amphosol system are discussed.

5.5.1 Bench-scale Results

In our bench-scale experiments, the first property measured is surface tension. Pure Amphosol solutions have been tested by Mevawalla [59] and the critical micelle concentration is reported to be 50ppm. **Figure 55** describes the variation trend of surface tension at different polymer concentrations with the addition of Amphosol. All three lines are starting at 68 dyne/cm with no surfactant and remaining stable at 33dyne/cm at 200ppm surfactant concentration. It is clear that CMC concentration can affect the CAC points with the comparison between different polymer concentrations with presence of Amphosol. (14ppm for 100ppm CMC solution, 20ppm for 500ppm CMC solution and 31ppm for 500ppm CMC solutions). Little influence can be found on PSP concentration (150ppm).

Besides, the conductivity of prepared solutions are presented in **Figure 56**, with the addition of surfactant, the increasing trend of conductivity is constant, no difference on increasing slope can be found in critical micelle concentration.

At last, the shear viscosity of a variety combinations of CMC and Amphosol were tested and its relationship with shear rate was studied as well (Figure 50). Clearly, every line in (a), (b) and (c) is arranged in order from top to bottom with the increase of surfactant amount and they are paralleled to each other, which indicates that some interactions occurred during the mixing process of CMC and Amphosol. Pipeline data will show whether these interactions are positive or negative on DR ability.

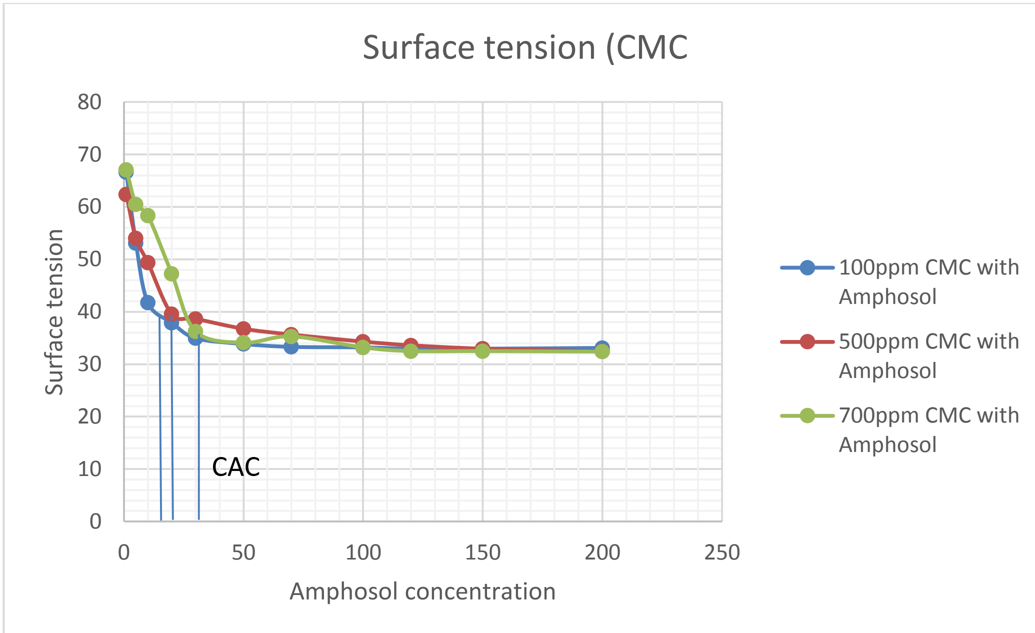


Figure 55 Surface Tension of CMC with Amphoteric

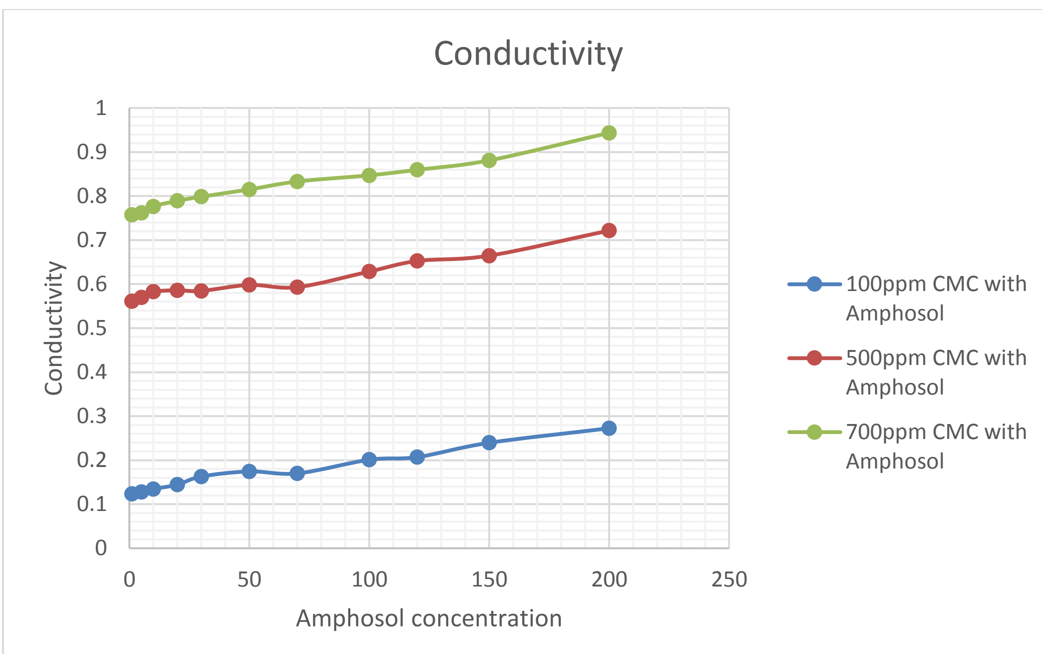


Figure 56 Conductivity of CMC with Amphoteric

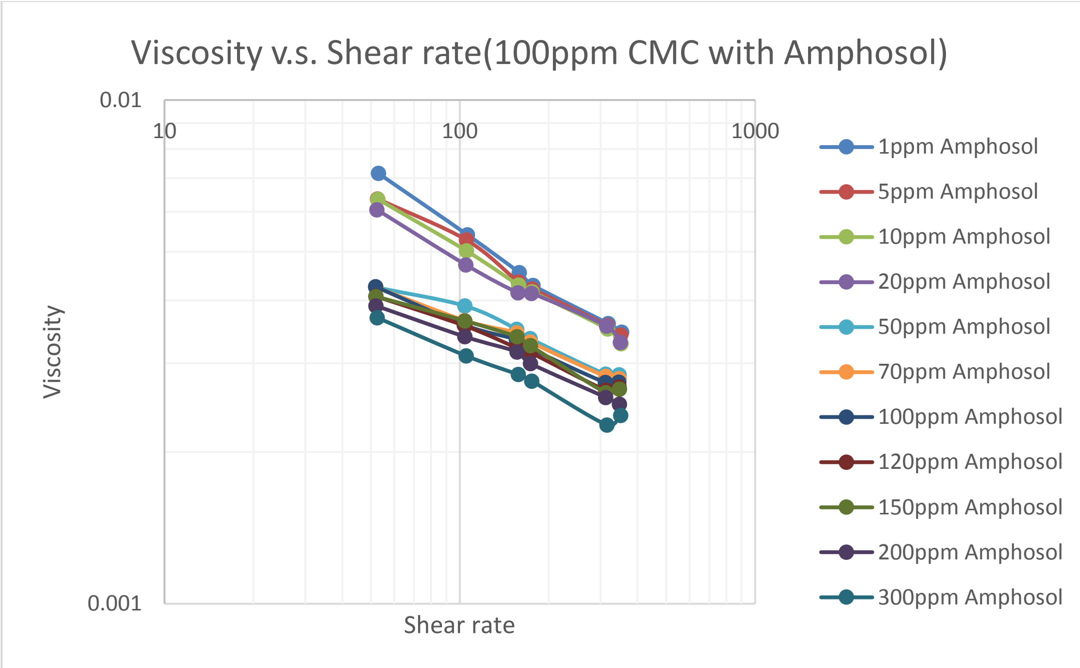


Figure 57 (a)

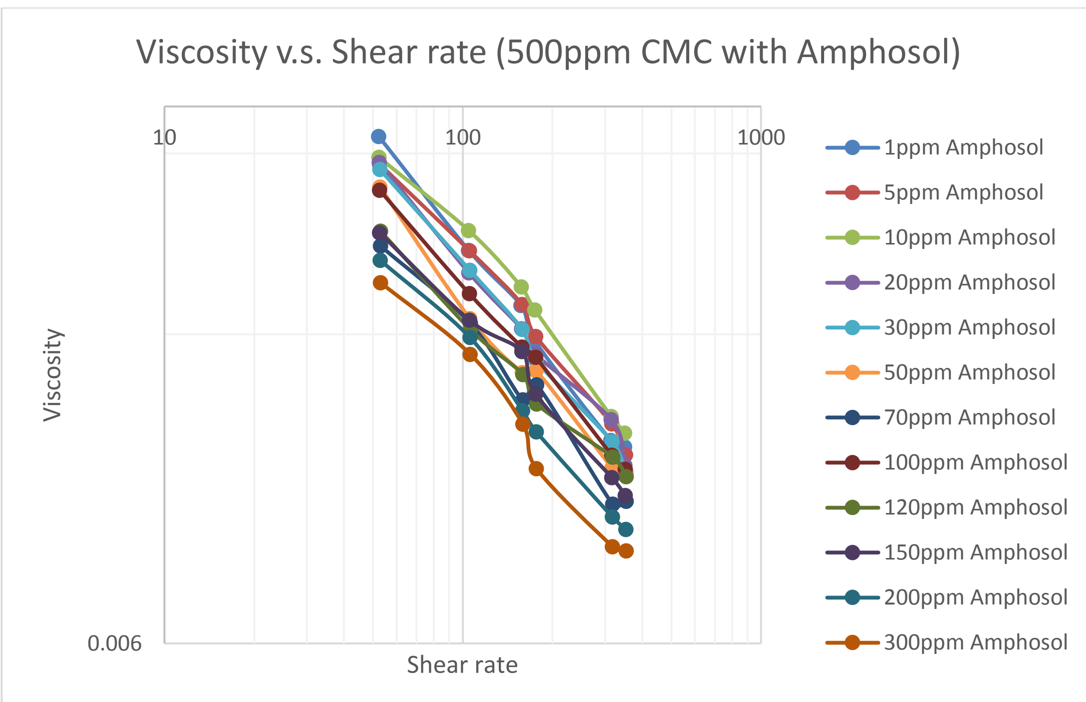


Figure 57 (b)

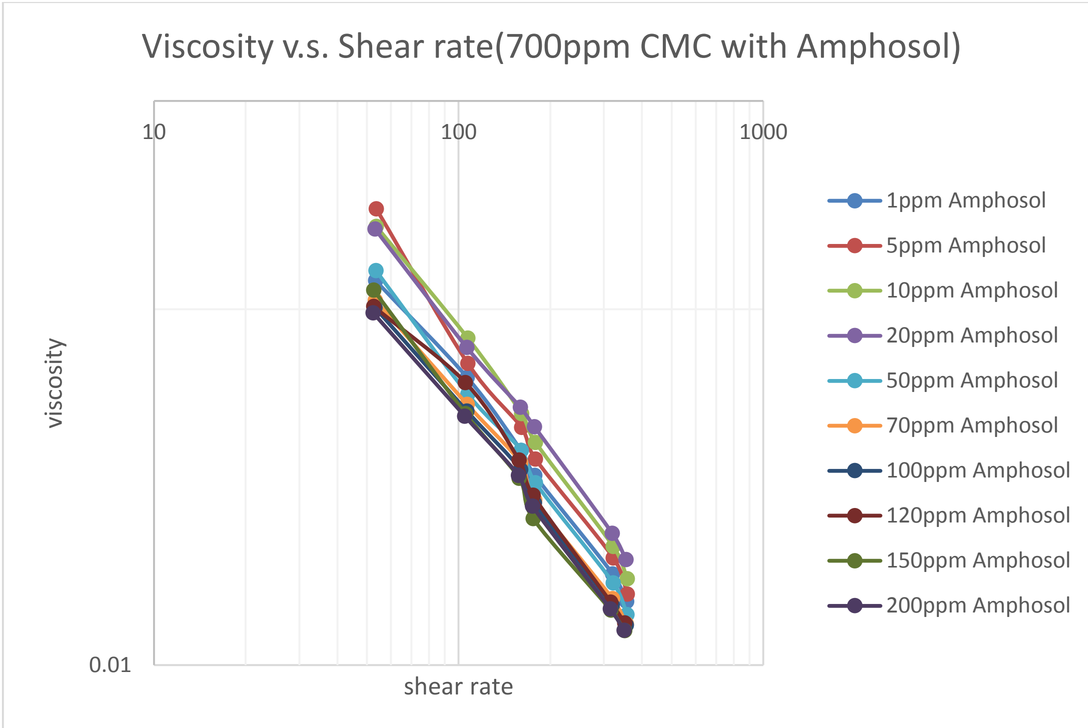


Figure 57 (c)

Figure 57 Shear Viscosity versus Shear Rate (CMC with Amphosol)

5.5.2 Pipeline Results

100ppm and 500ppm CMC with several surfactant concentrations solutions were prepared and tested in 1 and 1.5inch pipelines separately. No DR can be produced by pure 100ppm CMC solution which has been shown in Chapter 5 when comparing with Dodge-Metzner Equation. While according to pipeline behaviors of 100ppm CMC with presence of Amphosol (see **Figure 58** (a) to (f)), the synthetic effect of CMC and Amphosol do have a promotion on %DR. **Figure 58** (e) to (j) present 500ppm CMC with 100ppm and 300ppm Amphosol solutions in pipes. The exact %DR are calculated and listed in **Figure 59** and **Figure 60**.

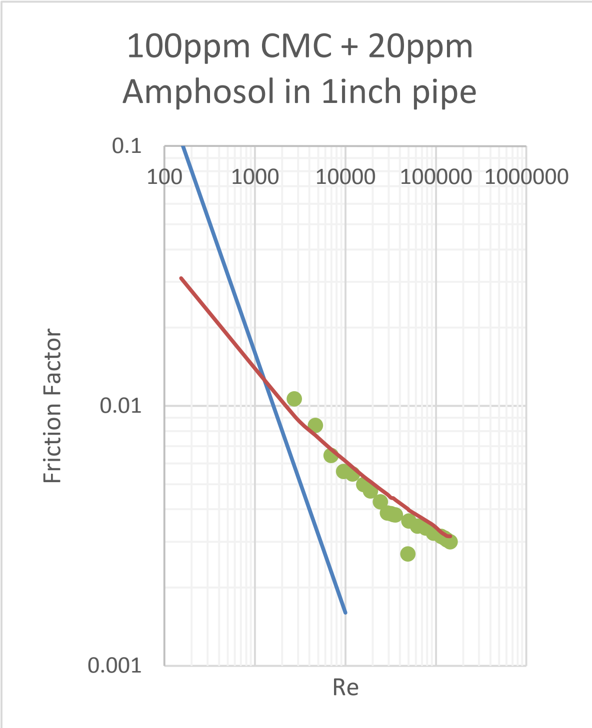


Figure 58 (a)

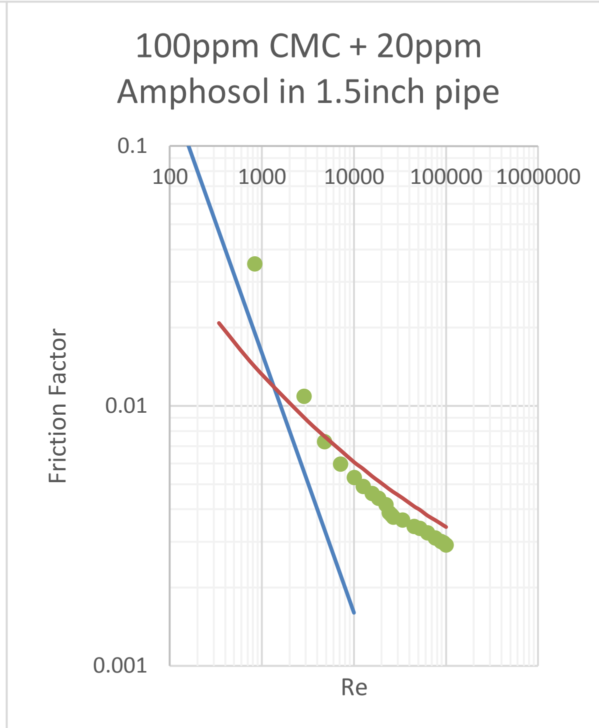


Figure 58 (b)

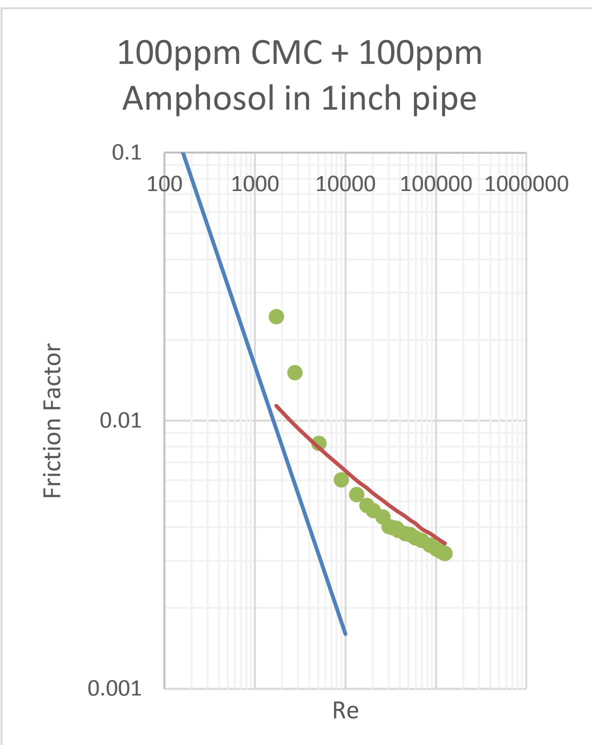


Figure 58 (c)

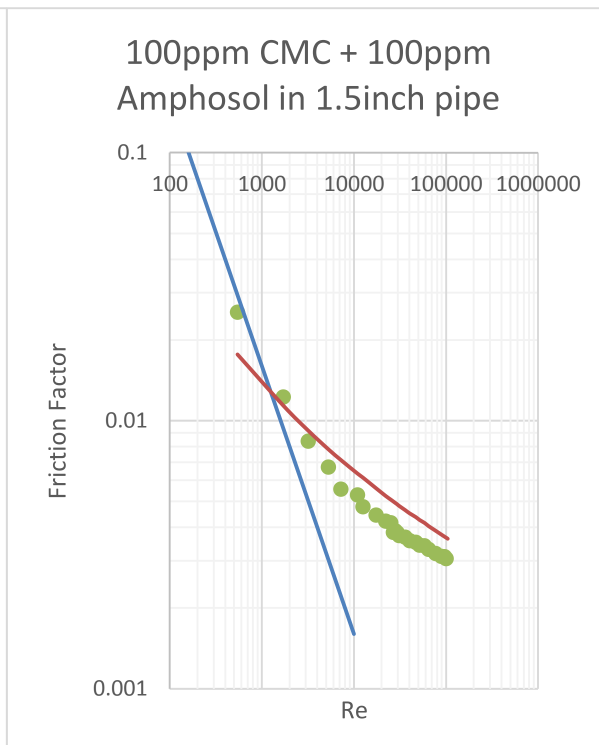


Figure 58 (d)

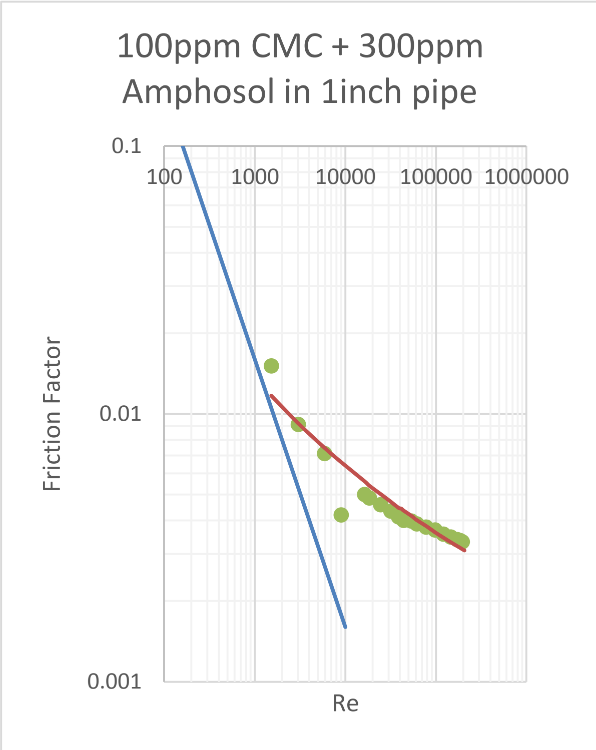


Figure 58 (e)

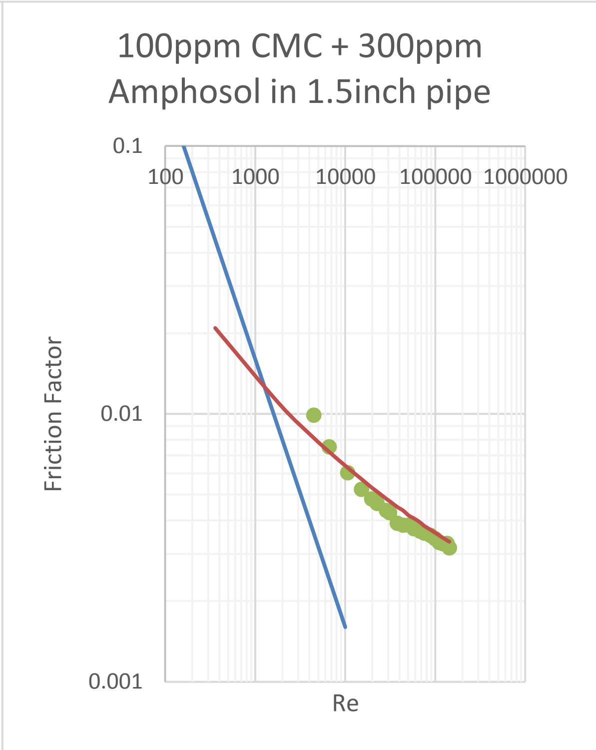


Figure 58 (f)

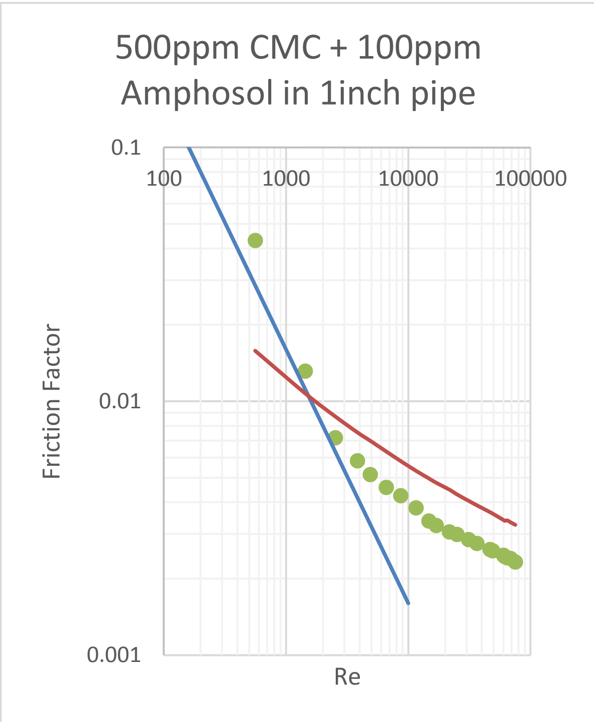


Figure 58 (g)

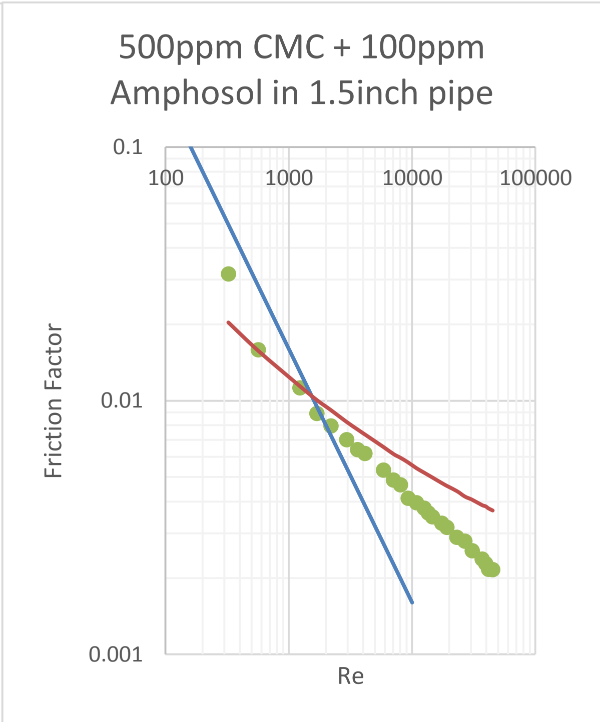


Figure 58 (h)

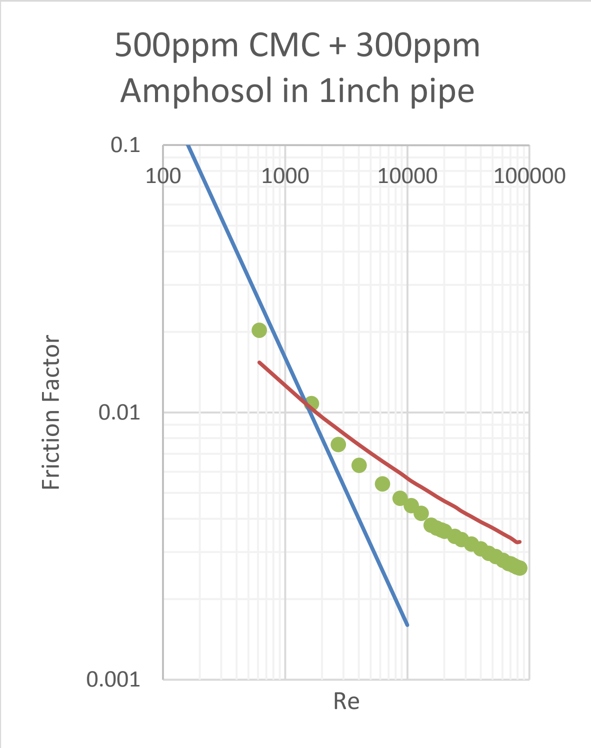


Figure 58 (i)

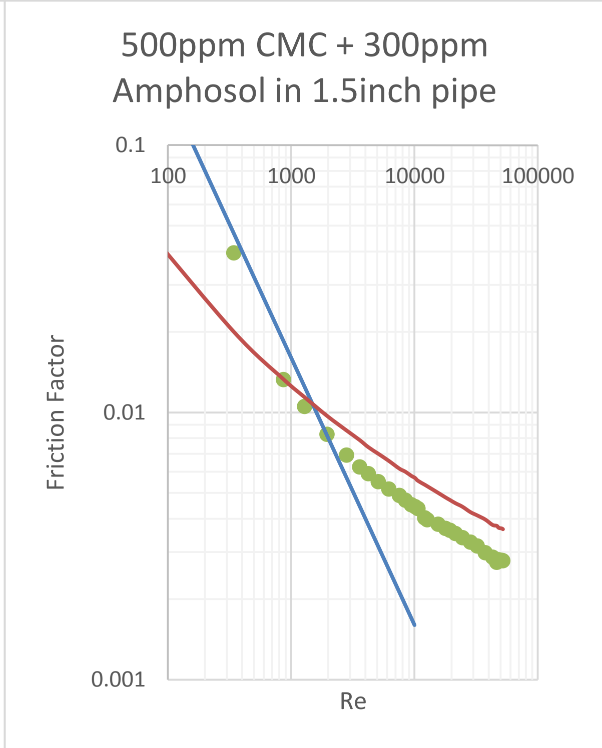


Figure 58 (j)

Figure 58 CMC with Amphosol Pipeline Behavior

(—— is Laminar Flow, —— is Dodge-Metzner Equation, ● are flow data)

From **Figure 59**, %DR of CMC with Amphosol solutions in 1inch and 1.5 inch pipes comparing with Blasius Equation are listed. Clearly, 500ppm CMC with 100ppm produces the highest DR ability in both pipes. In 1inch pipe, an addition of 300ppm surfactant in 500ppm CMC has almost the same %DR as pure CMC solutions, while in 1.5 inch pipe, the average %DR of 500ppm CMC solutions is 10% than that of 500ppm CMC with 300ppm Amphosol solutions, approximately. 100ppm CMC with Amphoteric solutions are tested as well. While, at low surfactant concentration (20ppm), little effect are investigated in both pipes. With the increase of Amphosol concentration, %DR go down drastically.

Correspondingly, when comparing with Dodge-Metzner Equation (see **Figure 60**), pure polymer solutions exhibit higher DR ability than those with surfactant at the same polymer concentration, for example, the %DR of 500ppm CMC is around 31.5% which is compared with 20.5% of 500ppm CMC with 300ppm Amphosol when Reynolds number is 50000. However, as for 100ppm CMC solutions, an addition of 20ppm surfactant contributes to a little bit higher %DR. So the ratio between polymer and surfactant concentration should be a vital important factor for DR ability.

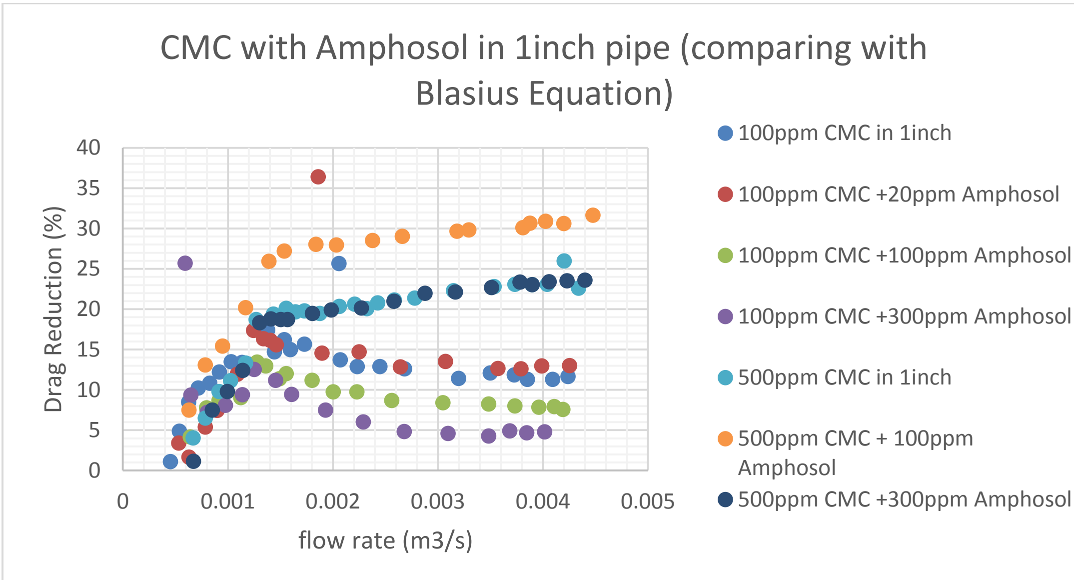


Figure 59 (a)

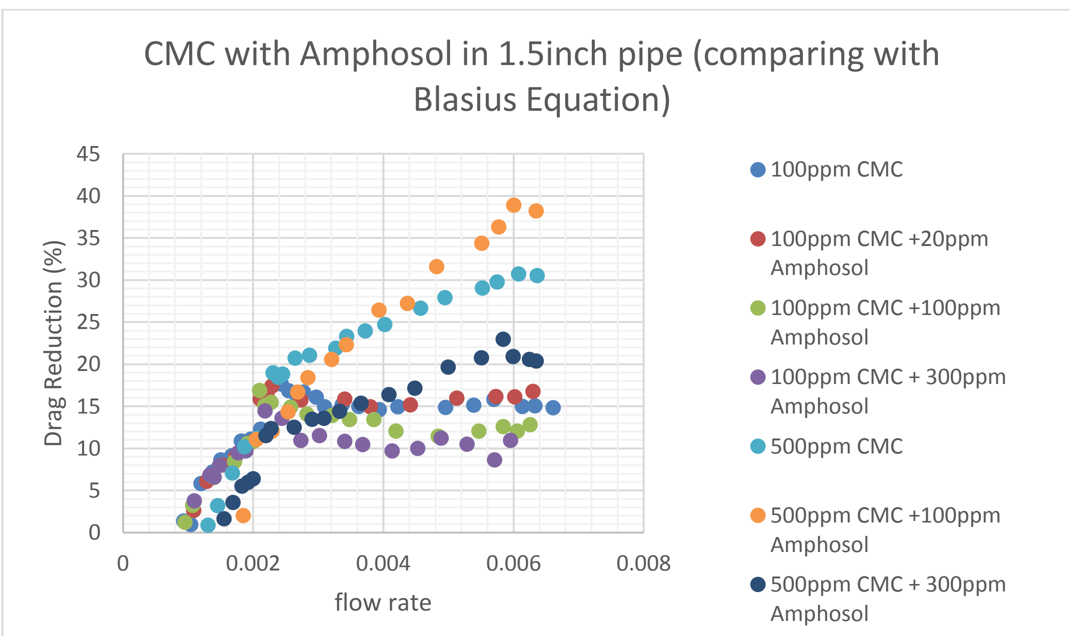


Figure 59 (b)

Figure 59 %DR of CMC with Ampholsol (comparing with Blasius Equation)

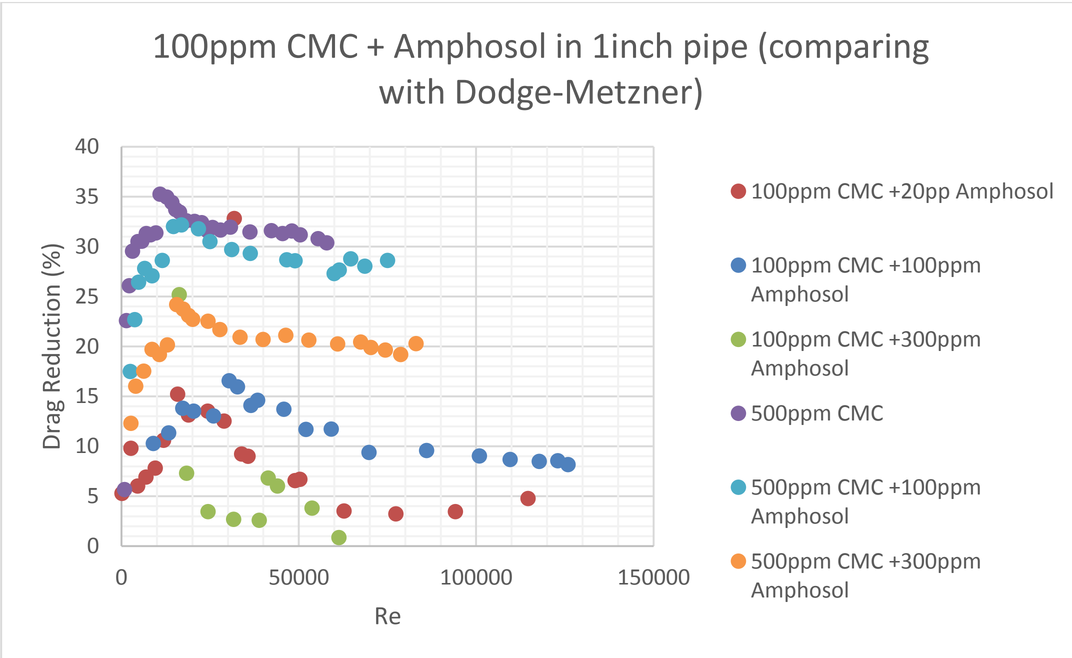


Figure 60 (a)

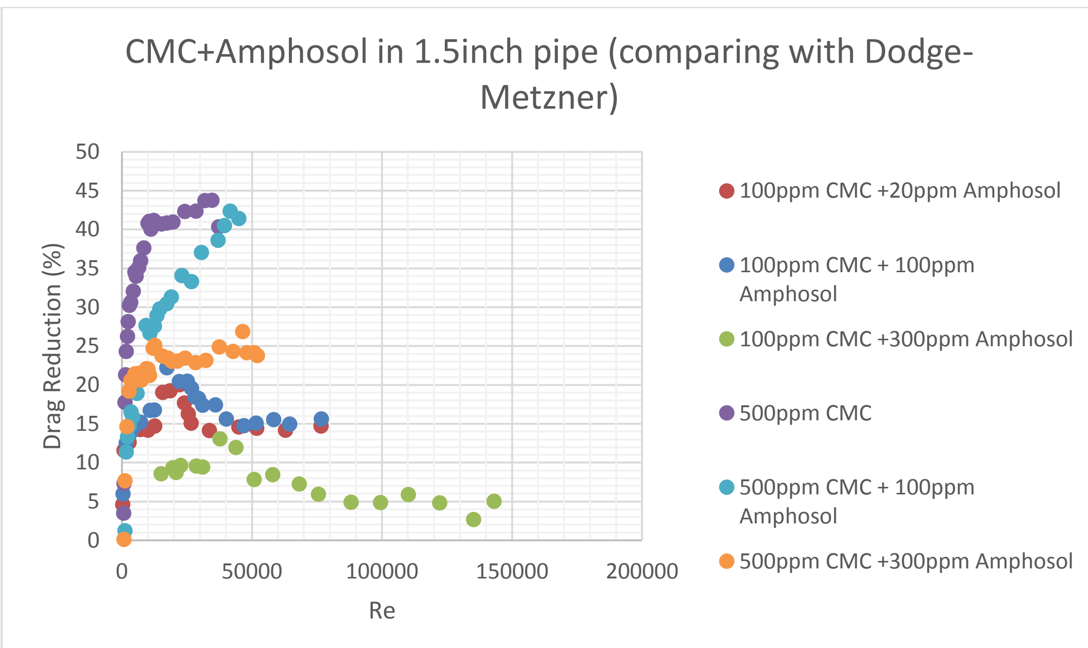


Figure 60 (b)

Figure 60 %DR of CMC with Amphosol (comparing with Dodge-Metzner Equation)

5.5.3 Conclusion

Amphosol is zwitterionic surfacatant which contains both positive and negative charges. CMC is anionic polymer. Mixing CMC and amphosol together, they can interact in two ways: Electrostatic interactions and hydrophobic interactions. Both of these interactions will have an effect on properties of fluids as well as pipeline behaviors.

- Critical micelle concentration is dependent on polymer concentration, with the comparison between 100ppm 300ppm and 500ppm polymer concentrations, an increase in CAC is found. While, polymer concentration has no effect on polymer saturation point (PSP), they remain at 150ppm, which means when surfactant concentration is higher than 150ppm, all polymer molecules are controlled by surfactant. Free micelles will form with extra surfactant concentration.
- From **Figure 57**, when polymer concentration is constant, an addition of surfactant into polymer solutions will results in a decrease in shear viscosity at the same shear rate.
- Taking Newtonian fluid as standard, in 1inch pipe, Amphosol has a negative effect on DR except for 100ppm Amphosol in 500ppm CMC solution and 20ppm Amphosol in 100ppm CMC solution.
- Comparing with Non-Newtonian fluid, 100ppm CMC with presence of Amphosol solutions have abilities to reduce friction factor, which is compared with pure 100ppm CMC that no DR can be found in both 1 and 1.5 inch pipes. However, the interactions can break macromolecules and reduce the hydrophobic groups in polymer, which results in a decreasing trend in %DR with the increase of surfactant concentration.

Chapter 6
Polymer-polymer Studies

PAM and PEO are both great DR agents which has been proved for several years, while little investigation was applied to test the synthetic effect on DR. Mohsenipour[5] has measured the properties of PAM and PEO solutions separately and Mevawalla also did relative researches on PAM/PEO combinations.

In this section, PAM and PEO were mixed and prepared together with different combinations. The total polymer concentrations are fixed at 500ppm and 1000ppm specifically. Surface tension, Conductivity, shear viscosity and n&k values were measured and analyzed. After that, all the solutions were tested in 1 and 1.5 inch pipes to calculate %DR. A comparison between different combinations were also discussed.

6.1 Bench-scale Results

Du Noüy Ring method was first applied to prepared solutions to estimate changing trend of surface tension at different combinations. In order to make it more reliable, Axisymmetric Drop Shape Analysis (ADSA) was installed and utilized as well. According Monhsenipoure, the overlap concentration of PAM and PEO are 770ppm and 1500ppm, specifically. From **Figure 61**, comparing two methods at the same polymer concentration, little difference can be discovered. So, we can estimate that though ring method is not precise for surface tension measure measurement, but it is okay for predicting variation trend.

One thing need to mention is that, surface tension goes down significantly when increasing PEO fraction from 0% to 10%, bottoming at 10% PEO fraction, increases a little when PEO fraction is 20% and remains almost stable afterwards. Also, total 1000ppm polymer concentration has a lower surface tension than that of total 500ppm polymer concentration with the same tendency (61 dyne/cm and 62 dyne/cm specifically). Both of these indicates that 10% PEO fraction is a crucial point. It is supposed that when PAM/PEO ratio is higher than this value, a new type of interactions may occur.

Conductivity are listed in **Figure 62** with respect to PEO fraction. Since PEO is electrically neutral, pure PEO solutions almost had no conductivity which can be observed when PEO faction was 100%. Conductivities are fully determined by PAM concentration. At the same PEO fraction, the conductivities of total 1000ppm polymer concentration solutions are two times as those of total

500ppm polymer concentration solutions. With the increase of PEO fraction, both lines have decreasing trends, falling to almost 0 at 100% PEO fraction.

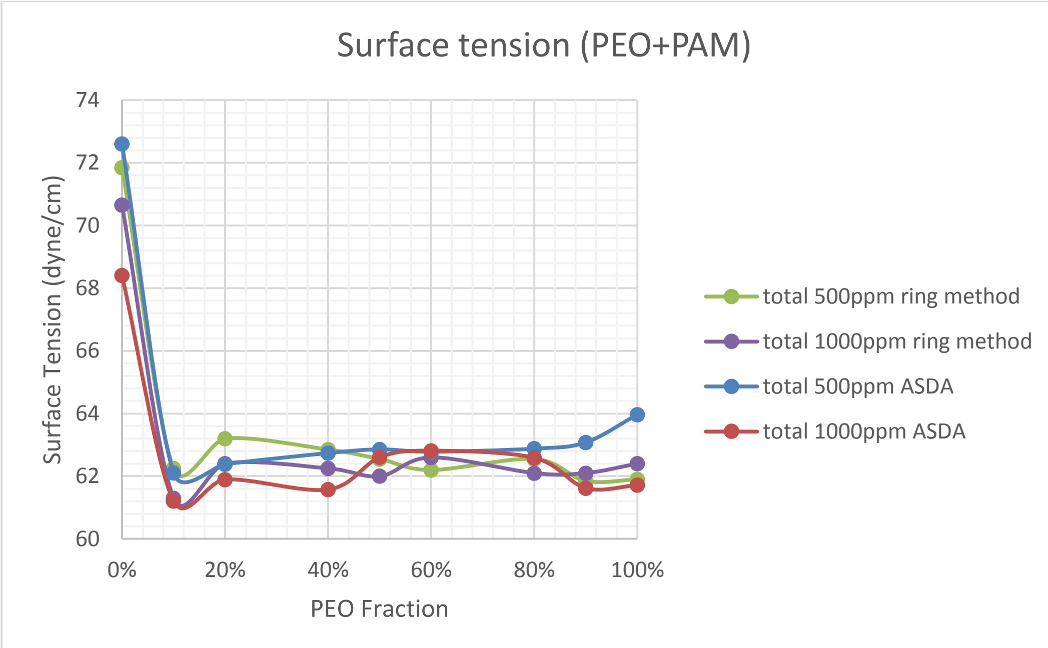


Figure 61 Surface Tension of PEO+PAM Combinations

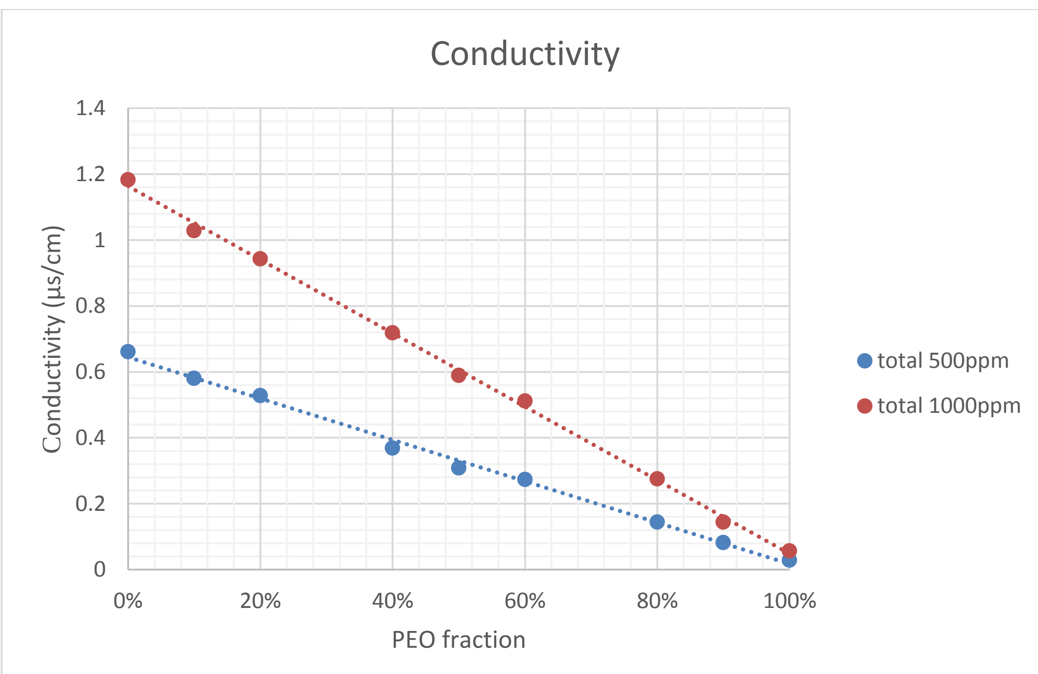


Figure 62 Conductivity of PEO+PAM Combinations

Meanwhile, shear viscosity was measured using coaxial cylinder viscometer (listed in Chapter 4), its relationship with shear rate is analyzed in **Figure 63** (a) and (b). According to it, each line is almost parallel to each other, which means the synthetic effects between PAM and PEO has changed the fluid properties. From low shear rate to high shear rate, shear viscosities keep going down, which present shear-thinning behavior. PAM and PEO are both shear-thinning fluids. Also, when PEO fraction is high, the spacing between every two combinations is increasing, which is possible because these two polymers can interact with each other intensively when PEO is sufficient.

In order to get a better understanding of shear viscosity, three angular speed were selected and their shear viscosity were analyzed with respect to PEO fraction. The results are shown in **Figure 64**. As we can see, for each total polymer concentration, the shear viscosities are decreasing with the increase of PEO fraction, bottoming at pure PEO solutions. Correspondingly, higher angular speed will result in lower shear viscosity which is easily discovered by comparing shear viscosity at the same PEO fraction from different angular speed. All the data are listed in **Table 6** and **Table 7**.

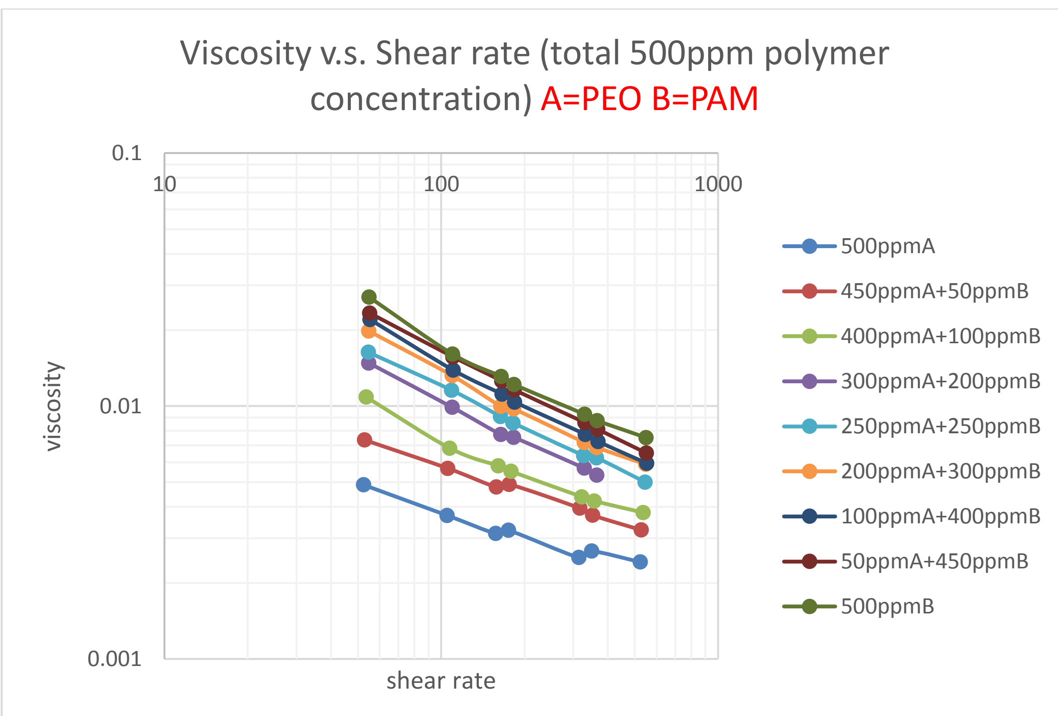


Figure 63 (a)

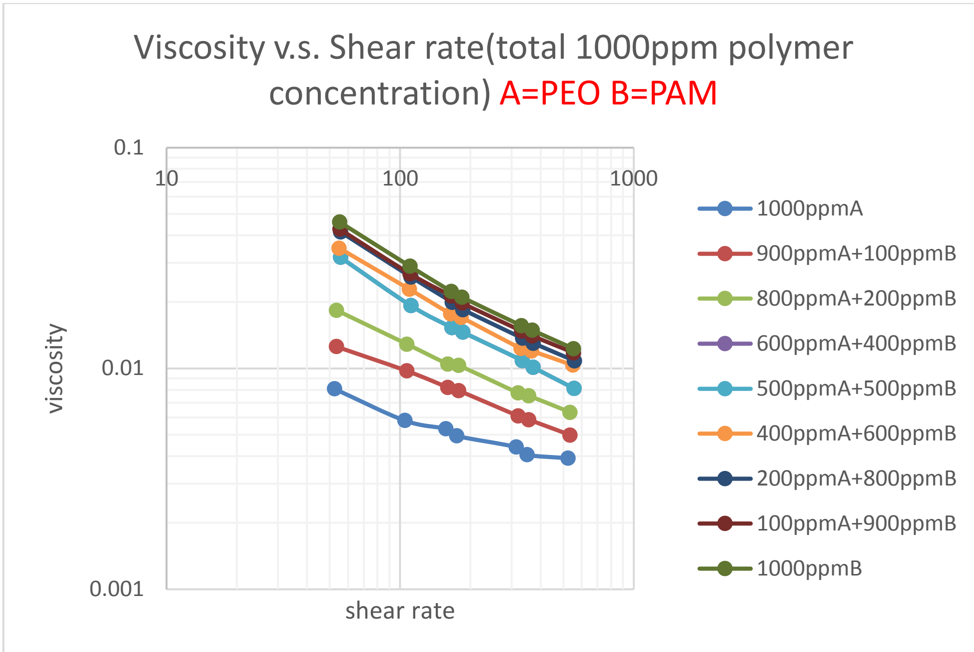


Figure 63 (b)

Figure 63 Shear Viscosity versus Shear Rate (PEO+PAM)

Table 6 Shear Viscosity at Different Angular Speed (total 500ppm)

TOTAL 500PPM			
PEO FRACTION	60RPM	100RPM	200RPM
100%	0.00369	0.003227	0.002671
90%	0.005675	0.004906	0.003703
80%	0.006821	0.005521	0.004214
60%	0.00989	0.007525	0.00553
50%	0.011549	0.008576	0.00625
40%	0.013191	0.009748	0.006825
20%	0.013861	0.010371	0.00724
10%	0.015652	0.011594	0.008096
0%	0.016046	0.012178	0.00876

Table 7 Shear Viscosity at Different Angular Speed (total 1000ppm)

TOTAL 500PPM

PEO FRACTION	60RPM	100RPM	200RPM
100%	0.00369	0.003227	0.002671
90%	0.005675	0.004906	0.003703
80%	0.006821	0.005521	0.004214
60%	0.00989	0.007525	0.00553
50%	0.011549	0.008576	0.00625
40%	0.013191	0.009748	0.006825
20%	0.013861	0.010371	0.00724
10%	0.015652	0.011594	0.008096
0%	0.016046	0.012178	0.00876

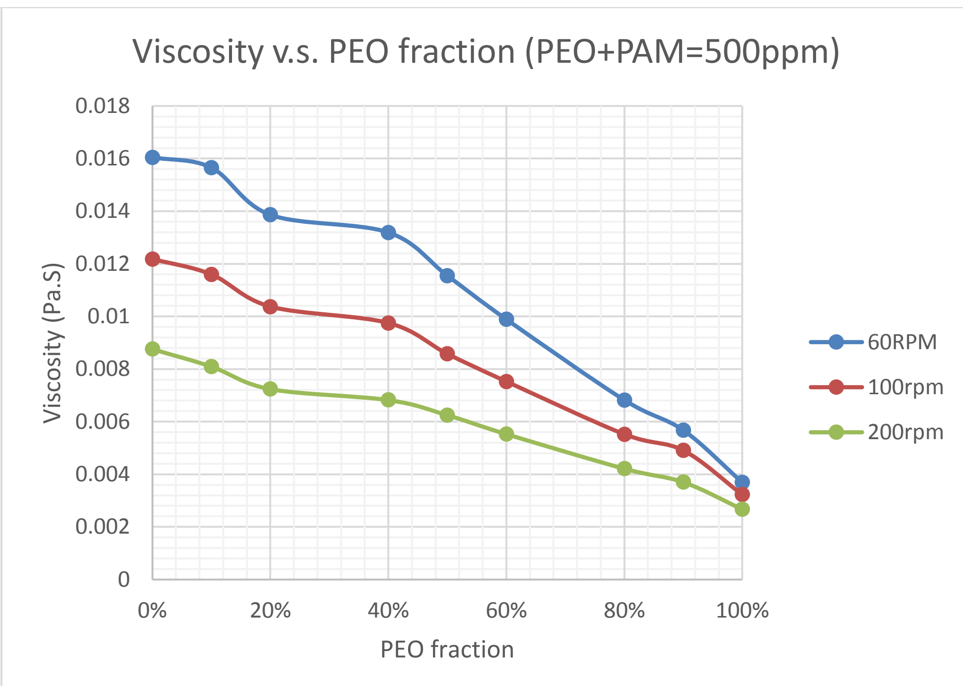


Figure 64 (a)

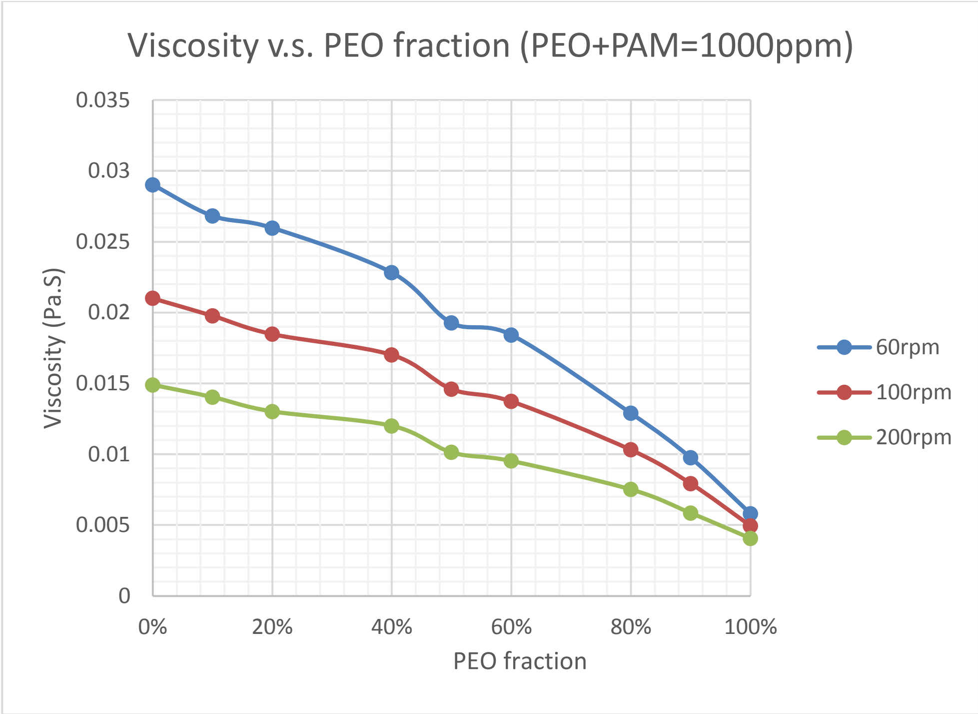


Figure 64 (b)

Figure 64 Shear Viscosity versus PEO Fraction

Table 8 and **Figure 64** present the power-law constant n and k values which are vital important for Non-Newtonian fluids. They determine the properties of solutions. The relationship between n&k and polymer fraction are the influencing factor for pipelines flow behaviors.

From **Figure 65**, at different total polymer concentration, there is no big difference shown in n value (n values of total 1000ppm solutions are slightly smaller than those of total 500ppm solutions). Also, with the increase of PEO fraction, n values are kept increasing, starting from 0.45 at 0% PEO fraction to 0.7 at 100% PEO fraction. However, when PEO fraction is 60% for 500ppm solution and 50% for 1000ppm solution, a small dip is shown on the results.

As for k values, total 1000ppm polymer concentration solutions have higher values. The increasing PEO fraction makes them decreasing gradually except for two slight rise at 20% and 50% PEO fraction. 500ppm solution exhibits the same trend with slight fluctuations.

After investigations about bench-scale properties of polymer-polymer solutions, the pipeline behavior are illustrated in the next part.

Table 8 N&K Values for PAM+PEO Solutions

TOTAL 500PPM					
PEO FRACTION	100%	90%	80%	60%	50%
N	0.6922	0.6478	0.5507	0.468	0.4864
K	0.0157	0.0295	0.0593	0.1214	0.1266
PEO FRACTION	40%	20%	10%	0%	
N	0.4671	0.4374	0.4478	0.4686	
K	0.1602	0.2014	0.2111	0.2052	

TOTAL 1000PPM					
PEO FRACTION	100%	90%	80%	60%	50%
N	0.7102	0.5923	0.5385	0.4436	0.4211
K	0.02335	0.0646	0.1123	0.2535	0.3079
PEO FRACTION	40%	20%	10%	0%	
N	0.4629	0.4164	0.4417	0.4478	
K	0.2865	0.4105	0.3799	0.3925	

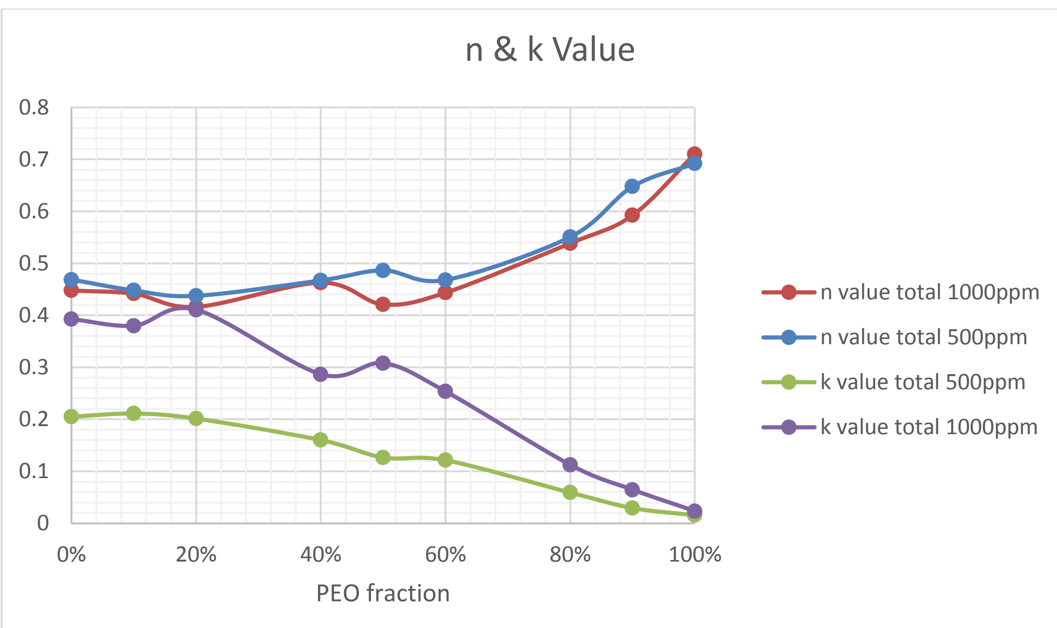


Figure 65 N&K Values versus PEO Fraction

6.2 Pipeline Results

6.2.1 Total 500ppm polymer concentration

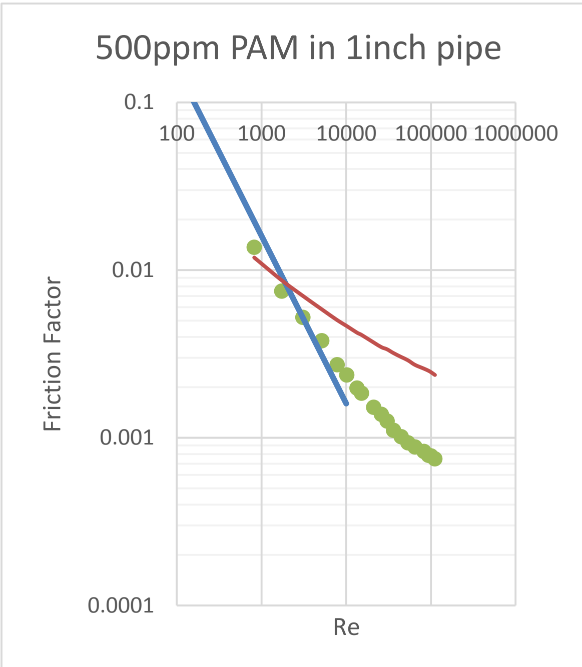


Figure 66 (a)

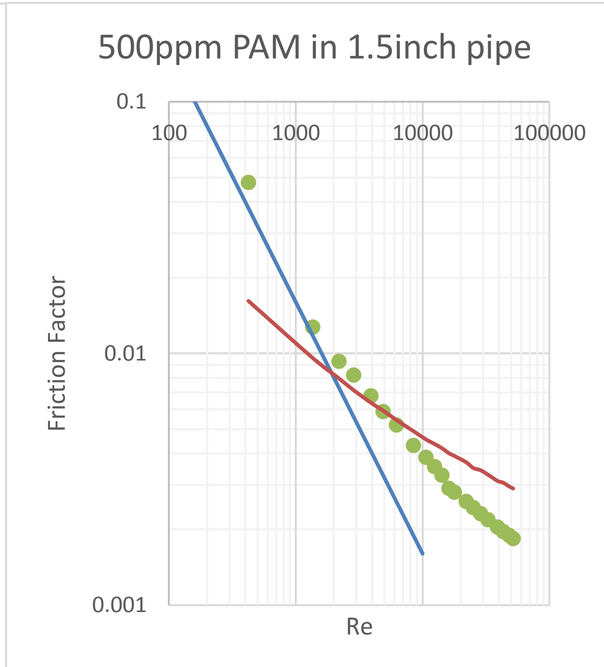


Figure 66 (b)

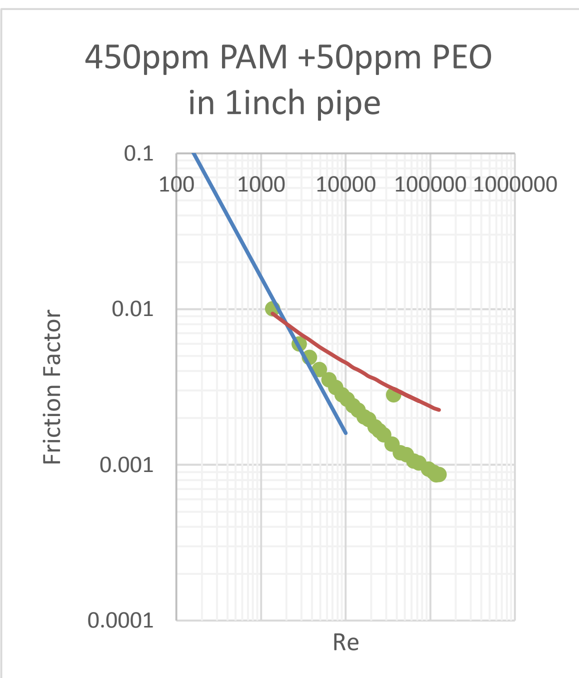


Figure 66 (c)

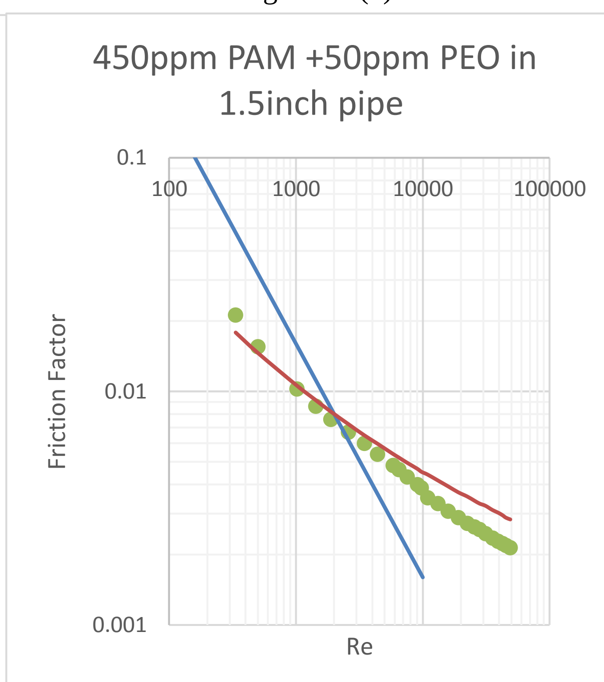


Figure 66 (d)

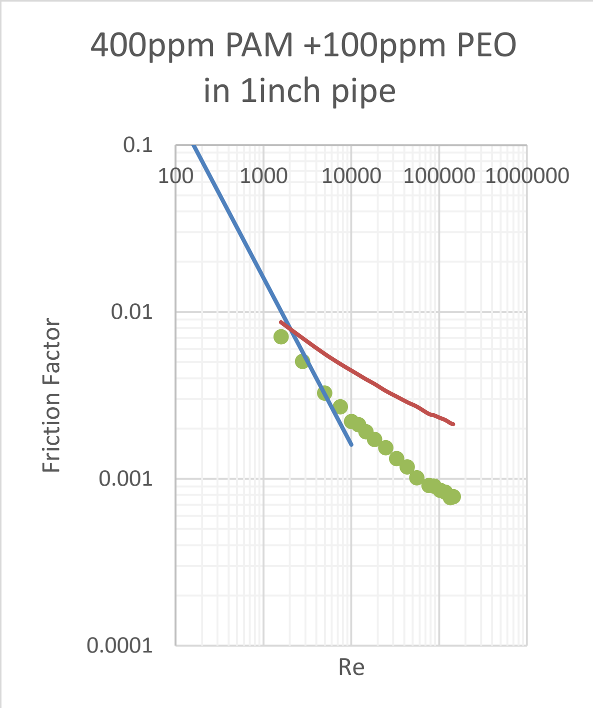


Figure 66 (e)

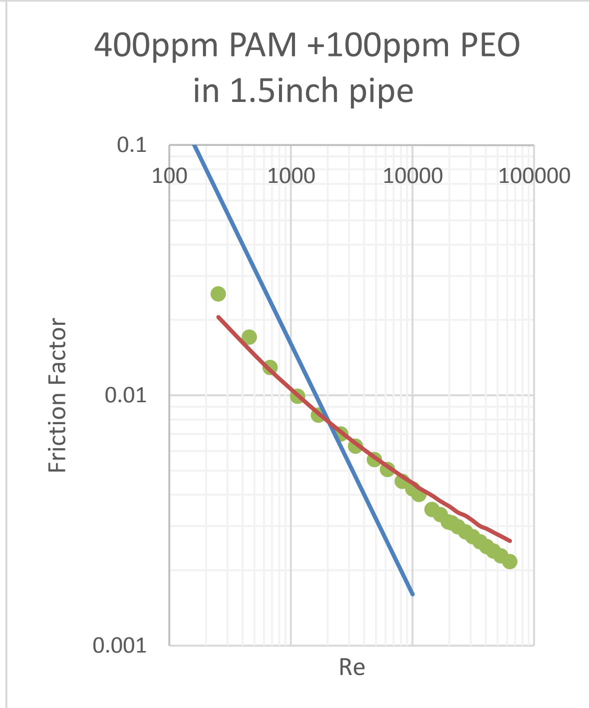


Figure 66 (f)

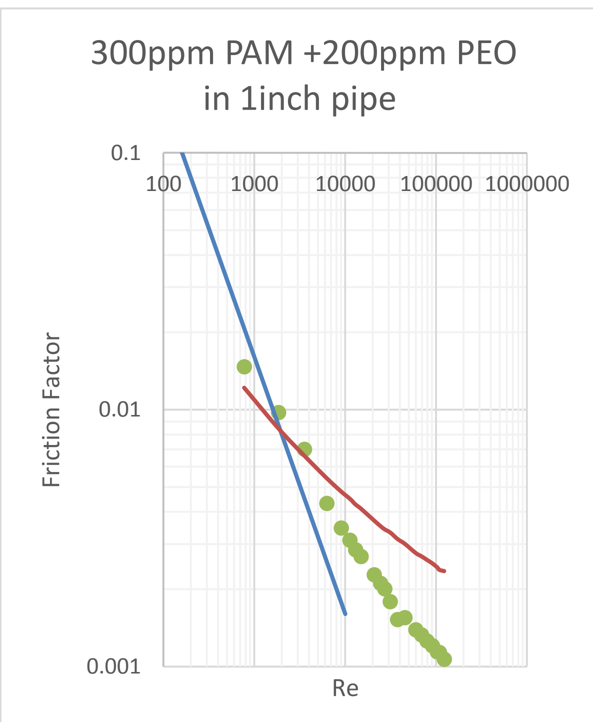


Figure 66 (g)

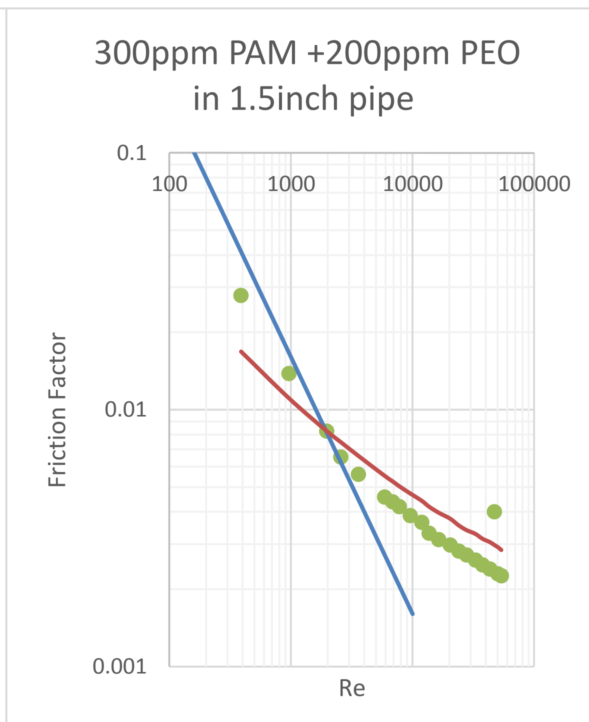
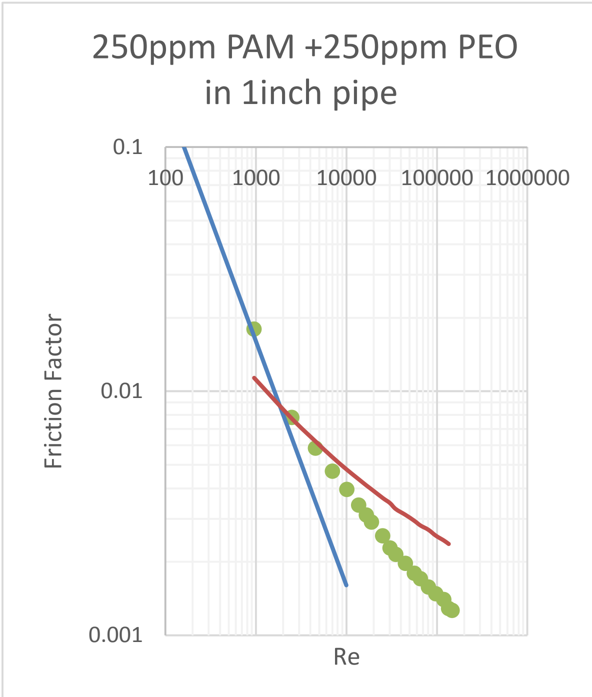


Figure 66 (h)



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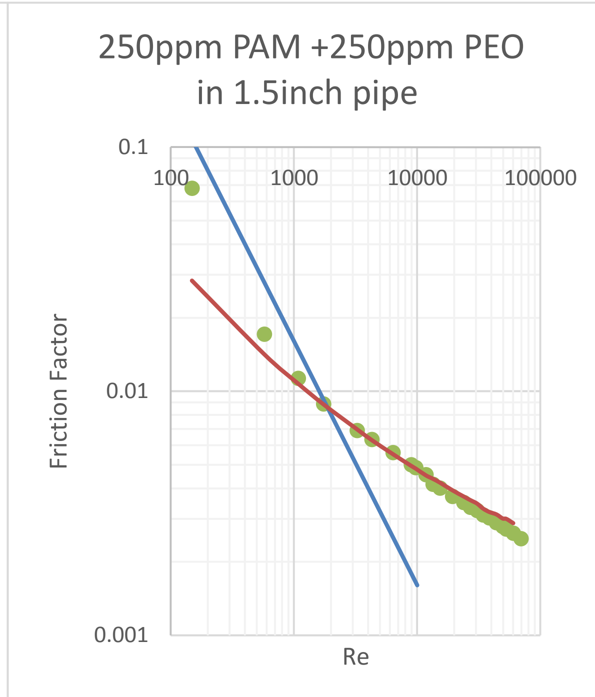

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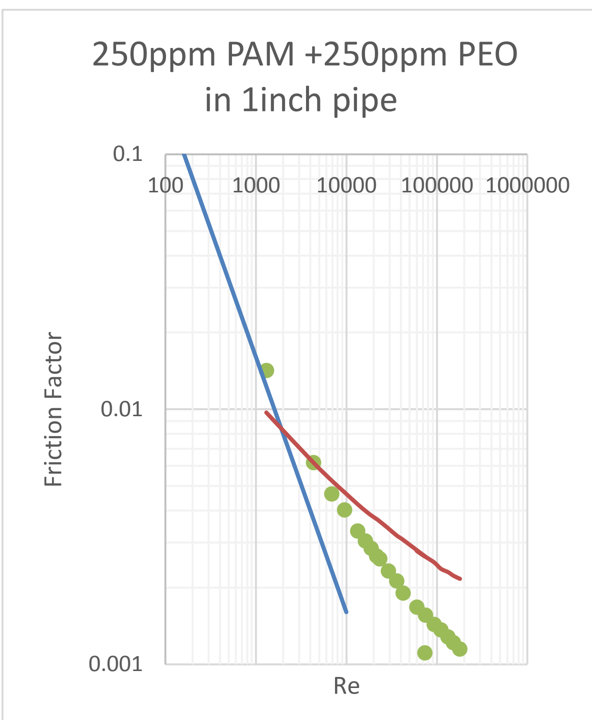


Figure 66 (k)

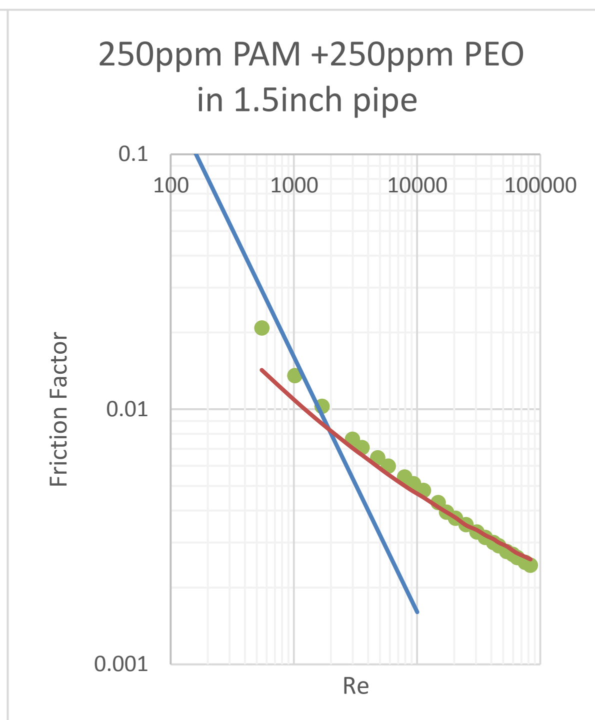


Figure 66 (l)

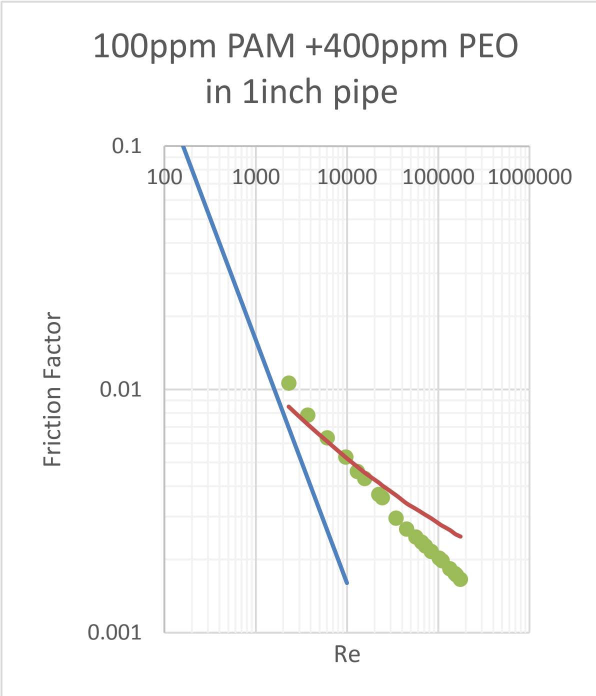


Figure 66 (m)

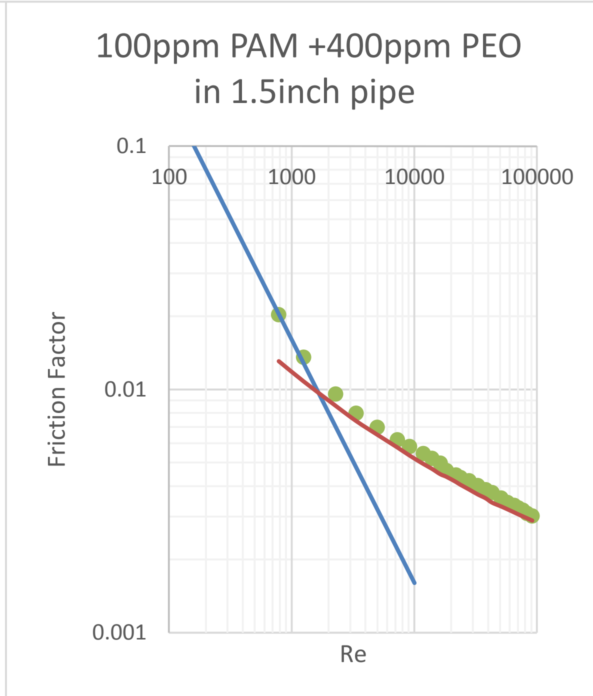


Figure 66 (n)

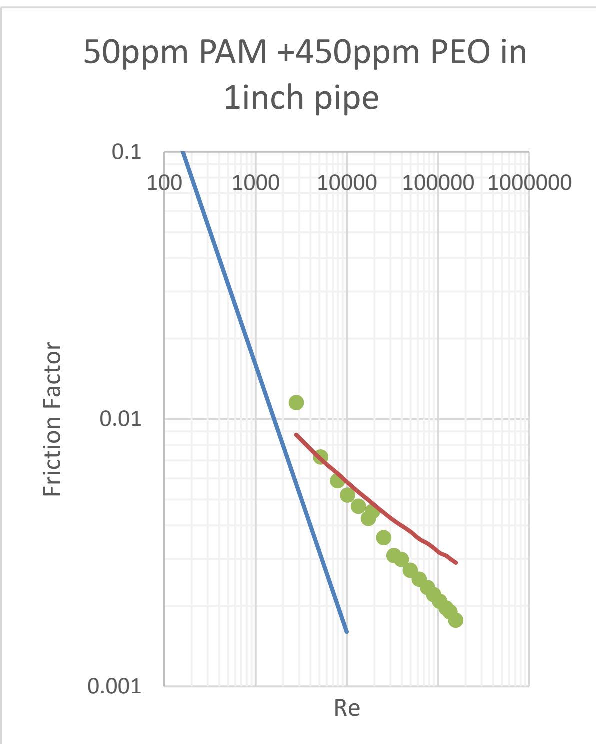


Figure 66 (o)

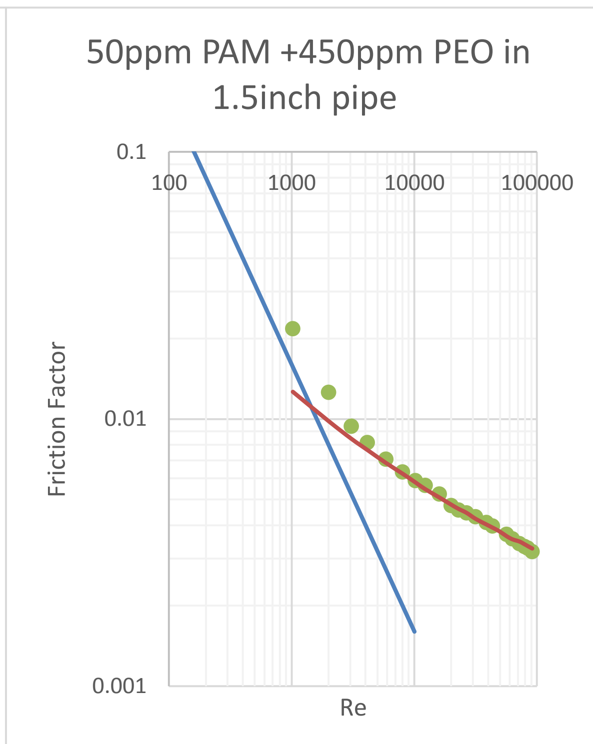


Figure 66 (p)

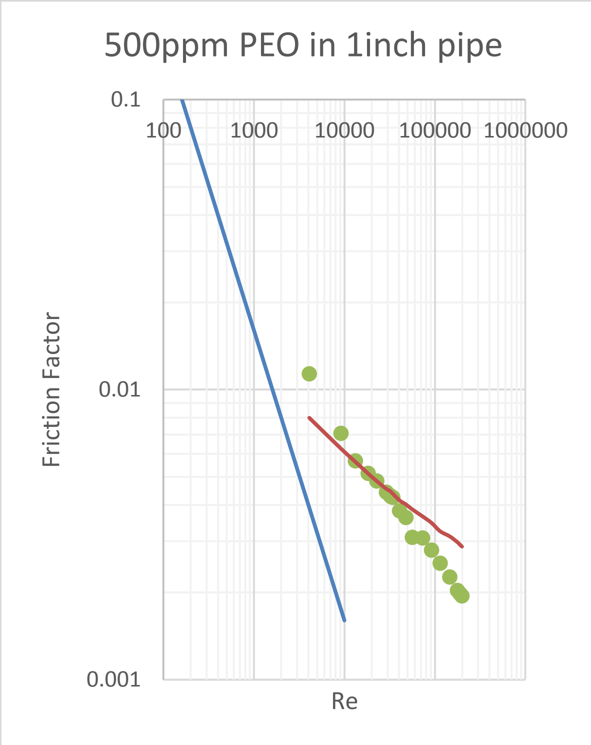


Figure 66 (q)

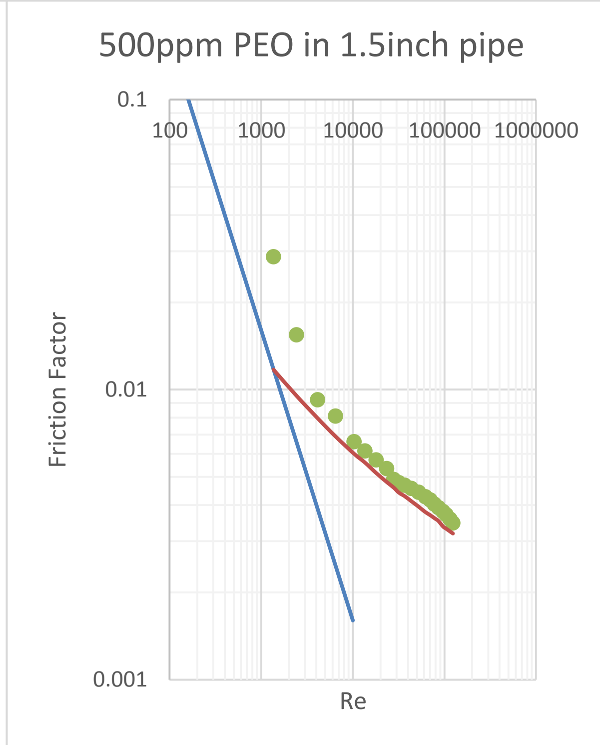


Figure 66 (r)

Figure 66 PAM+PEO Pipeline Behavior (total 500ppm)

(——— is Laminar Flow, ——— is Dodge-Metzner Equation, ● are flow data)

A variety of combinations of PAM+PEO system with 500ppm total polymer concentration solutions were tested in 1 and 1.5 inch pipes specifically. The pipeline behavior of each solution is presented in **Figure 66** (a) to (r).

From these figures, we can directly estimate that the %DR are decreasing all the time with the increase of PEO fraction. When PEO fraction is high enough, no obvious DR can be found in 1.5inch pipe (in contrast to Dodge-Metzner Equation). At the same concentration, %DR in 1inch is considered higher than that in 1.5inch by estimation. Calculations are required to analyze %DR comparing with Newtonian flow at the same flow rate. The final results are shown in **Figure 67** and **Figure 68**.

From Figure 67, when Blasius Equation is regarded as standard equation, significant DR ability can be observed. Pure 500ppm solutions have the highest %DR, reaching 78% at 0.005m^3/s in 1inch pipe and 47.5% at 0.0064m^3/s in 1.5 inch pipe approximately. However, pure 500ppm PEO solution only have %DR about 43% in 1inch pipe and 3% inch pipe, which are much lower than pure CMC solution. At low flow rate in 1.5inch, DR can be barely found when PEO fraction is high. One interesting thing is the PEO fraction has a postpone effect on the onset of DR in both pipe. Totally, by increasing PEO concentration and remaining total polymer concentration at 500ppm, the total %DR have falling trends in both pipes.

In contrast to Dodge –Metzner Equation, similar results are shown in **Figure 68** only with relative lower DR abilities. Interestingly, when PEO domain the solution (PEO fraction is higher than 60%) in 1.5 inch pipe, no DR can be calculated in a range of Reynolds number from 1000 to 80000. By comparison, PAM is a better drag-reducer than PEO

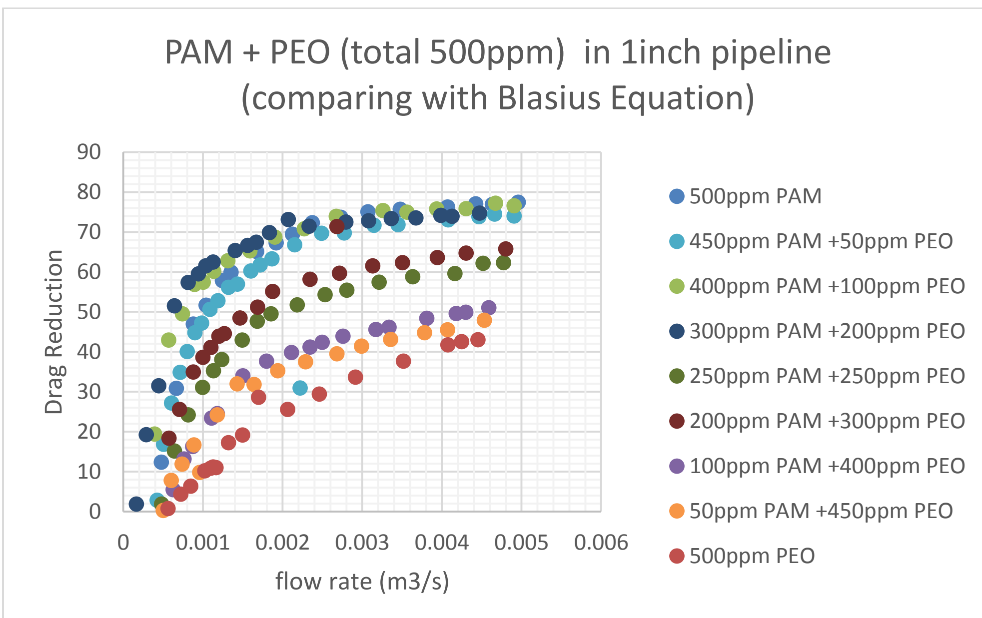


Figure 67 (a)

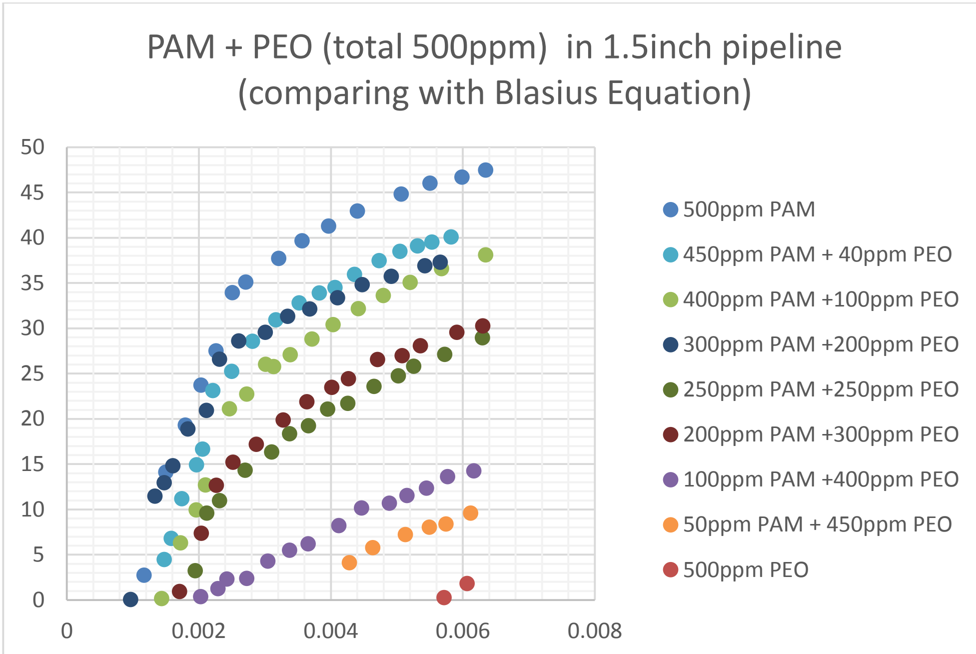


Figure 67 (b)

Figure 67 %DR of PAM+PEO (total 500ppm) in Pipelines (comparing with Blasius Equation)

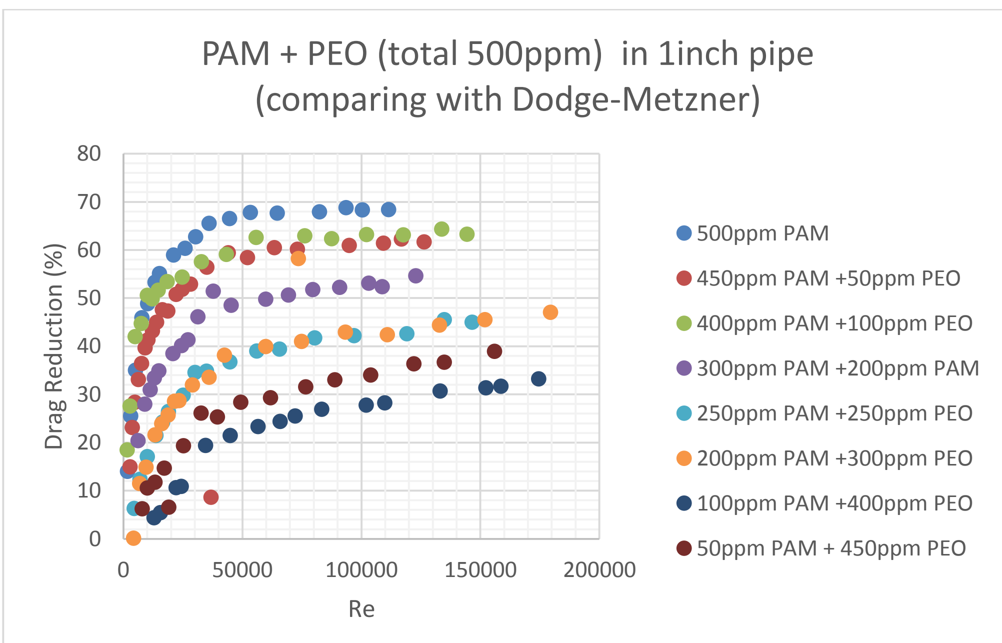


Figure 68 (a)

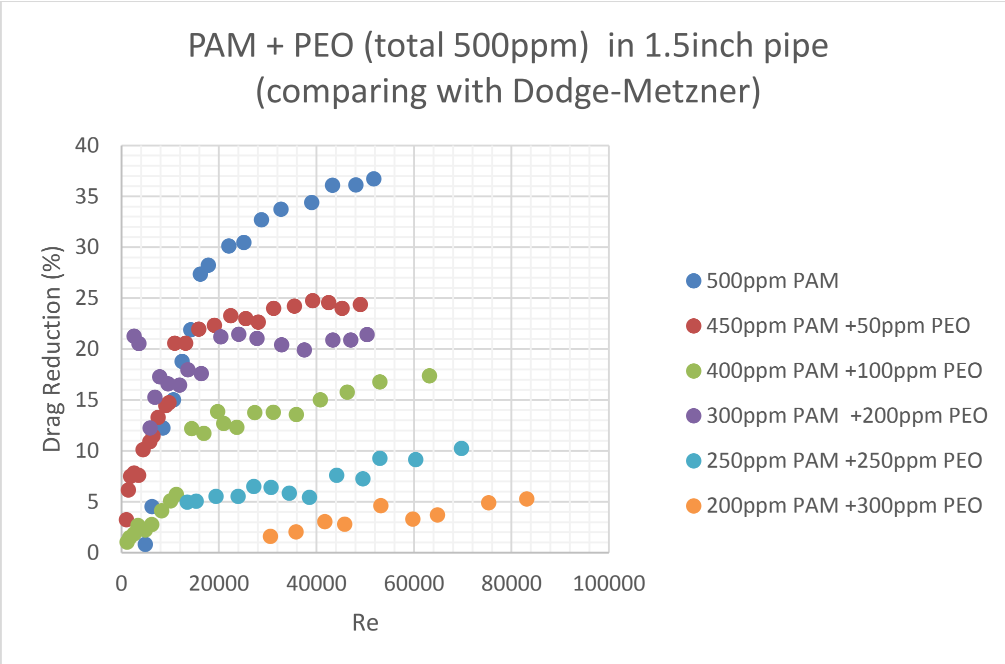


Figure 68 (b)

Figure 68 %DR of PAM+PEO (total 1000ppm) in Pipelines (comparing with Dodge-Metzner Equation)

6.2.2 Total 1000ppm polymer concentration

After measuring a variety of combinations PAM and PEO system at a total 500ppm polymer concentration, a series of total 1000ppm polymer concentration solutions were prepared and tested in the following. The pipeline behavior of every combination and %DR comparing with Newtonian fluids and Non-Newtonian fluids are listed in **Figure 69** to **Figure 70**.

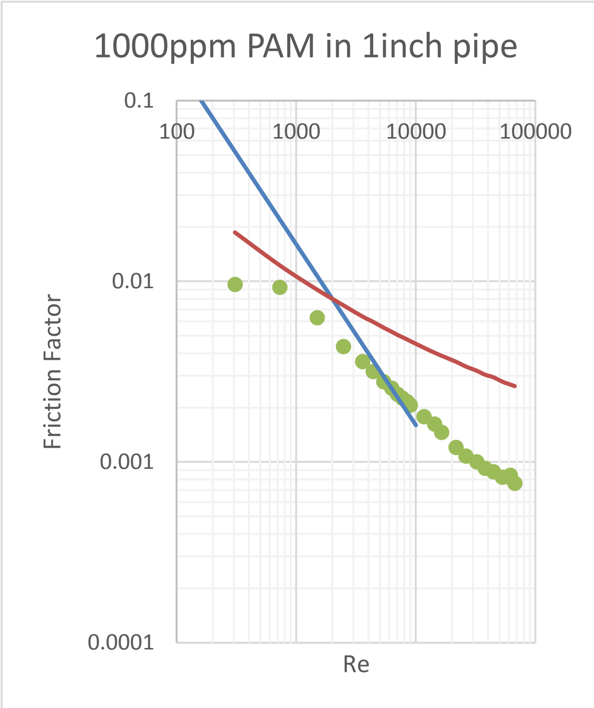


Figure 69 (a)

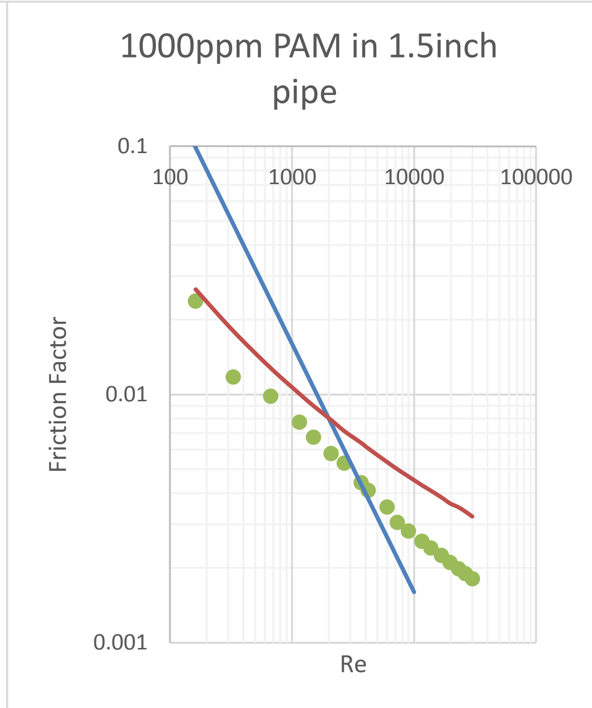


Figure 69 (b)

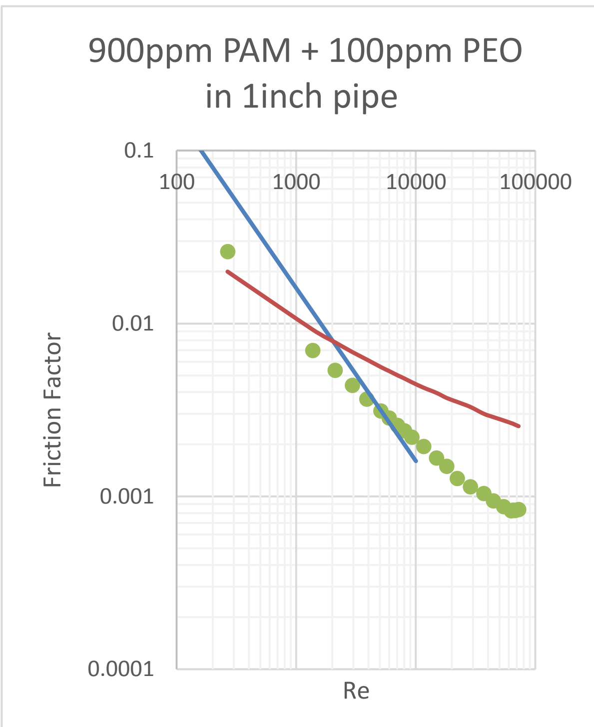


Figure 69 (c)

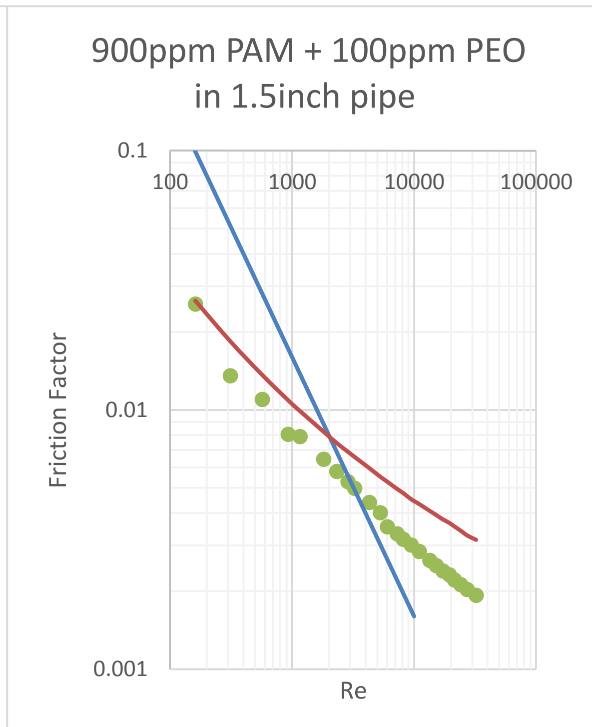


Figure 69 (d)

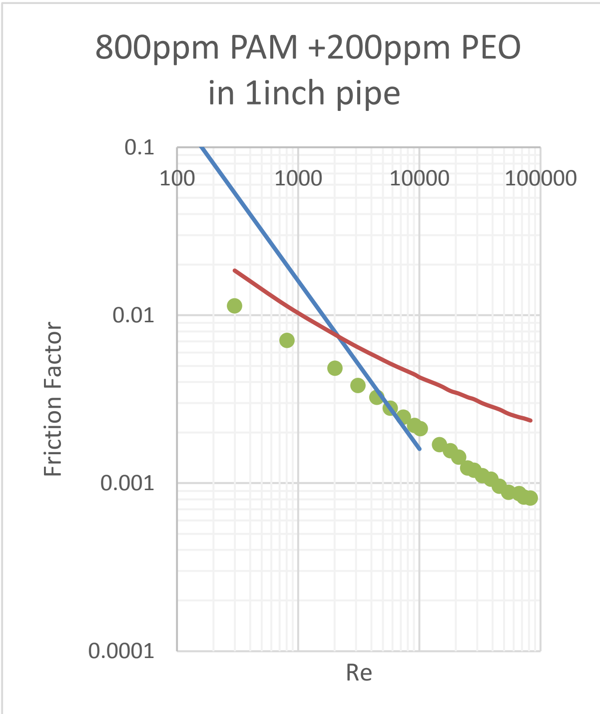


Figure 69 (e)

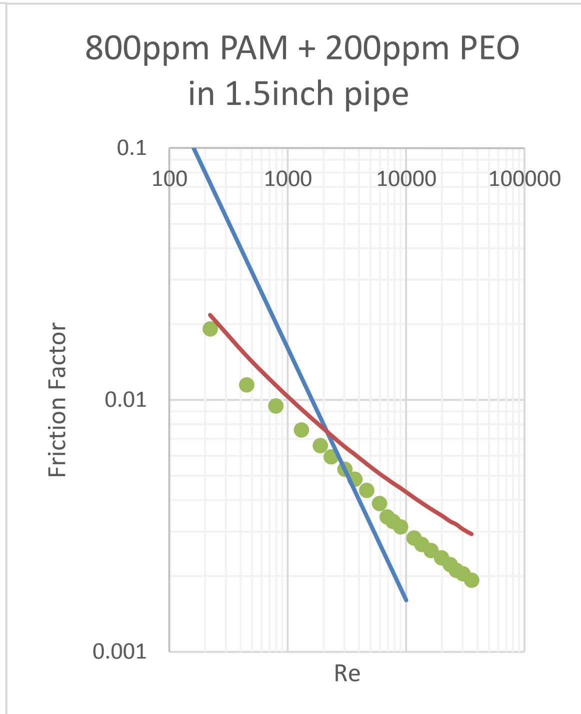


Figure 69 (f)

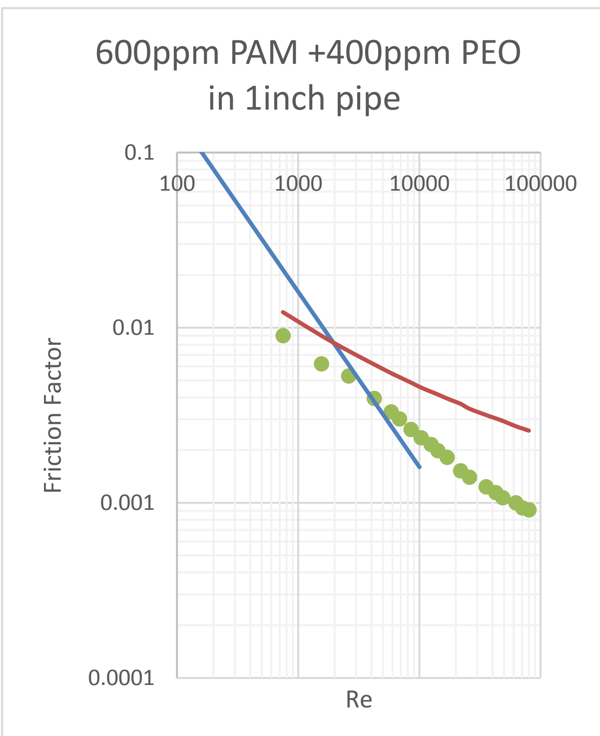


Figure 69 (g)

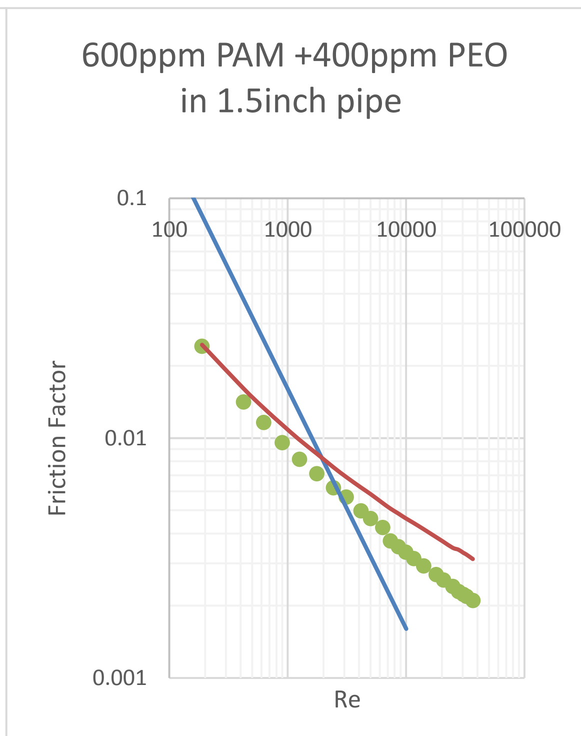


Figure 69 (h)

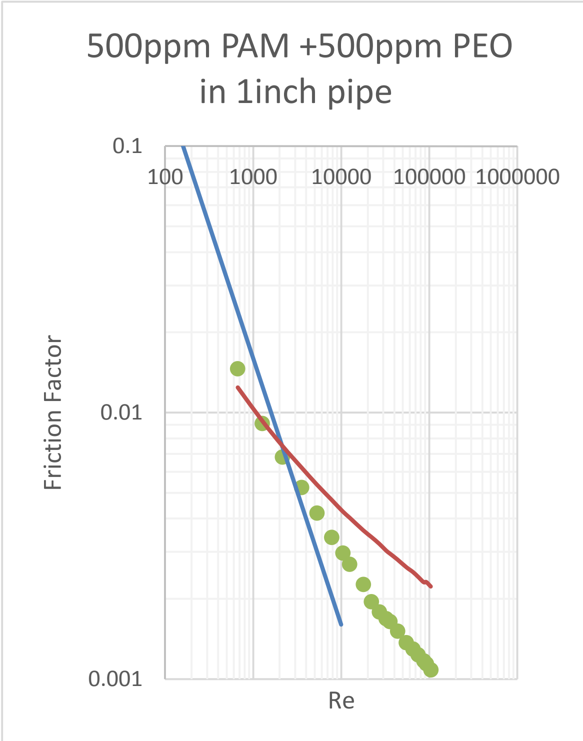


Figure 69 (i)

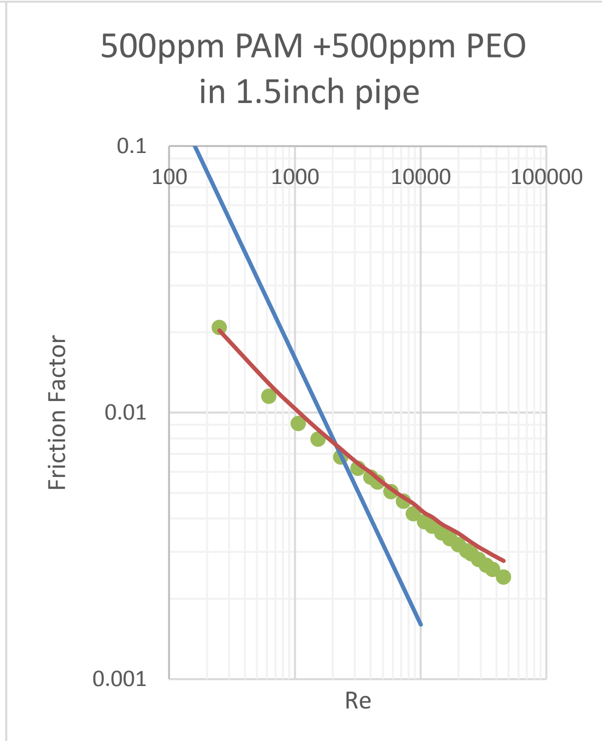


Figure 69 (j)

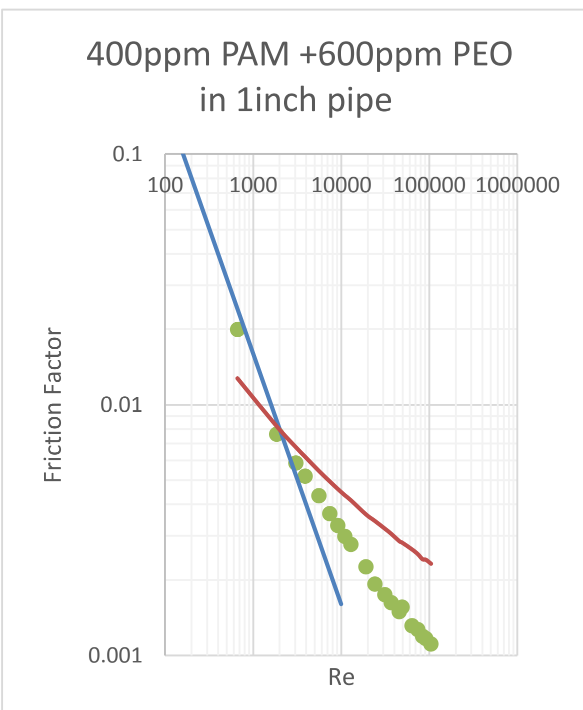


Figure 69 (k)

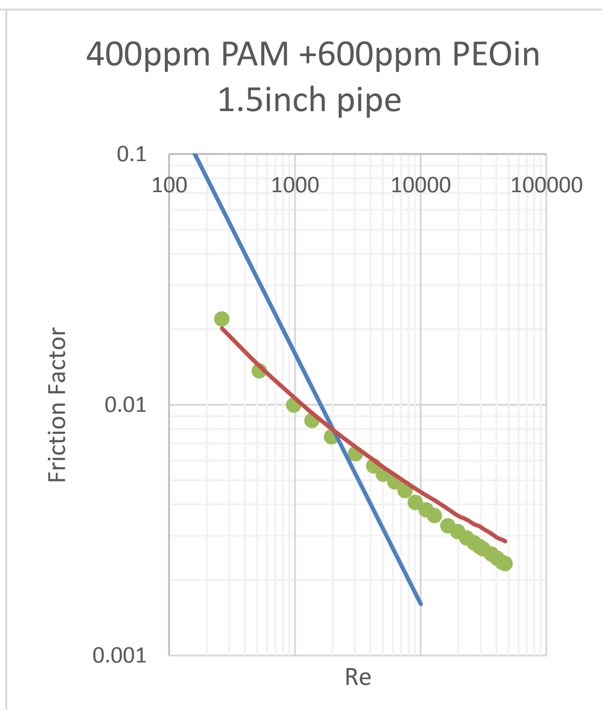


Figure 69 (l)

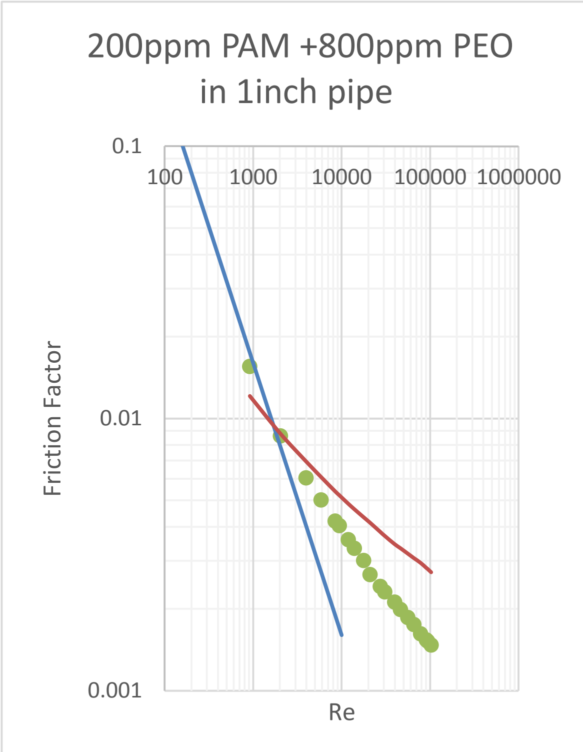


Figure 69 (m)

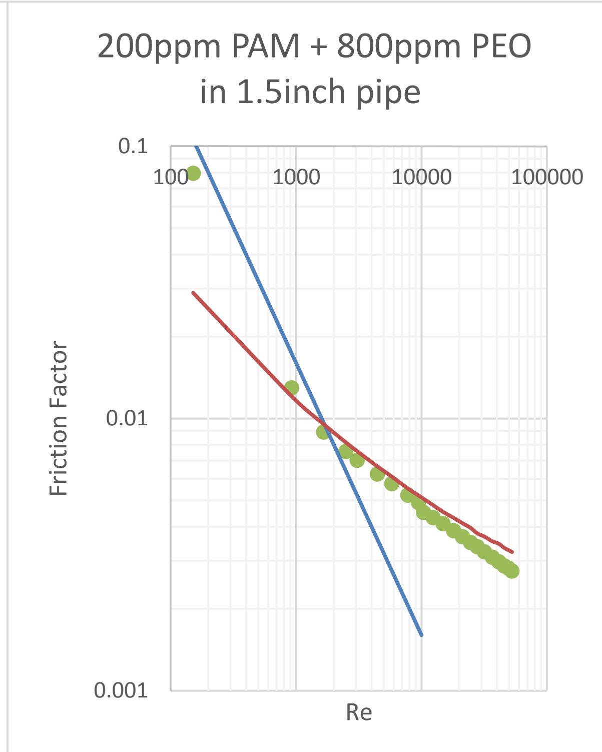


Figure 69 (n)

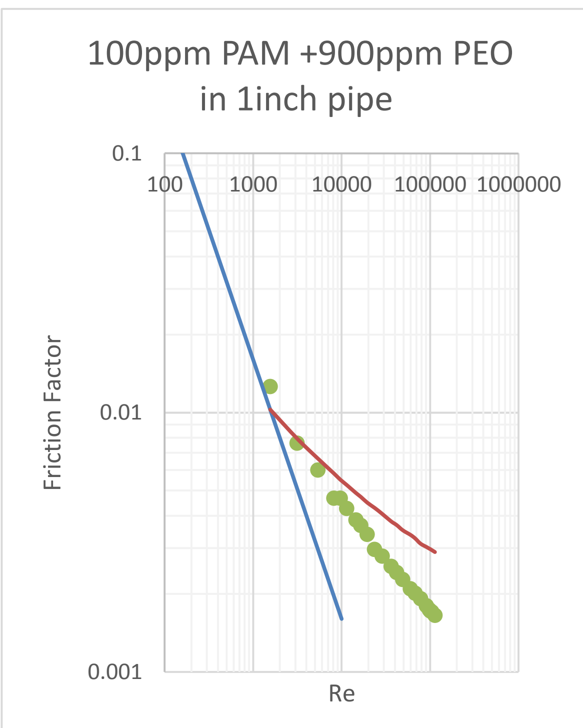


Figure 69 (o)

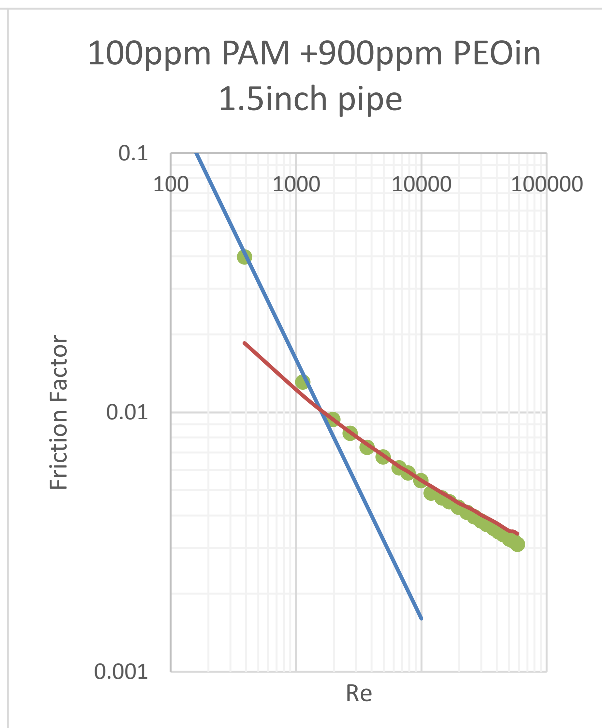


Figure 69 (p)

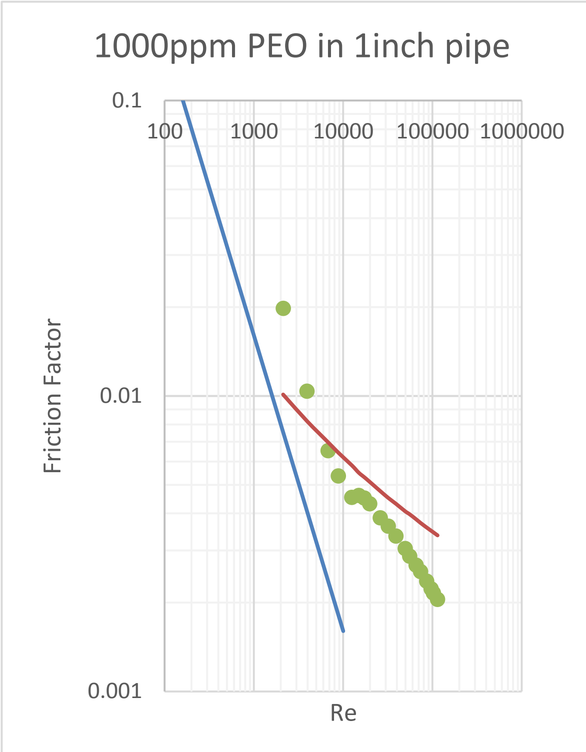


Figure 69 (q)

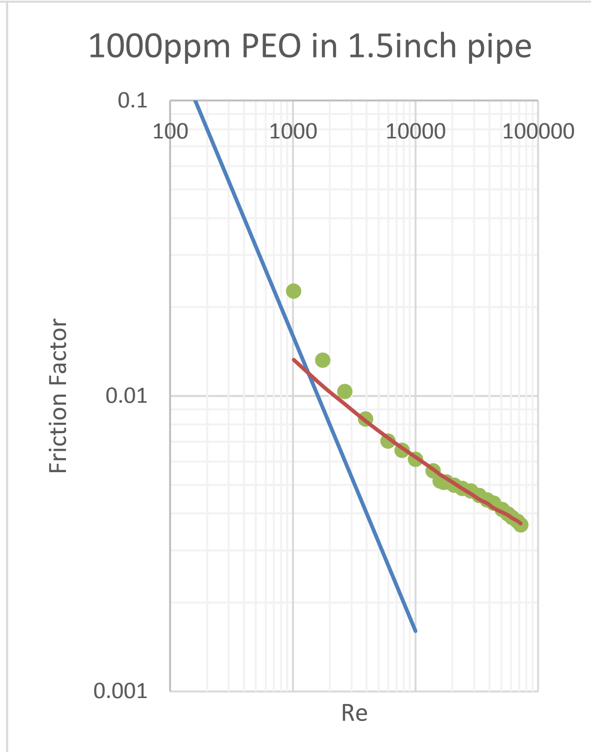


Figure 69 (r)

Figure 69 PAM+PEO Pipeline Behavior (total 1000ppm)

(is Laminar Flow, is Dodge-Metzner Equation, ● are flow data)

From pipeline behaviors of 1000ppm PAM/PEO system, we can easily estimate that %DR in 1 inch pipe is higher than that in 1.5inch when comparing with Dodge-Metzner Equation. Also, when PEO fraction is high, flow data in 1.5inch almost follows Dodge-Metzner Equation, which will result in 0 DR in pipe.

Figure 70 illustrates the %DR comparing with Blasius Equation, %DR is very high when PAM fraction is over 70%. With the increase of PEO fraction, %DR bottoms at 40% with 100% PEO fraction when flow rate is 0.0044m^3/s. In 1.5inch pipe, pure PEO solutions has no DR ability compared with water flow at the same flow rate. As we estimated, %DR in 1inch pipe is higher than that in 1.5 inch using the same solutions, for example, 1000ppm PAM produce 70% DR ability in 1inch pipe which is compared with 48% in 1.5 inch pipe. Thus, diameter effect plays an important role in PAM/PEO systems. In contrast to Dodge-Metzner Equation (**Figure 71**), higher PAM fraction will contribute to higher DR ability. One thing need to mention is that there is a sharp decrease in %DR when PEO fraction is higher than 50% in both pipes. According to the shear viscosity results shown earlier, interactions occur intensively in PAM/PEO system, which is the main factor of decrease in %DR. Further investigations are needed to determine the intensive interactions. Besides, in 1.5 inch pipe, DR of 1000ppm PEO solution gets started only when Reynolds number is higher than 70000. Due to the limitation of our set-ups, there is no higher Reynolds number can be reached and tested

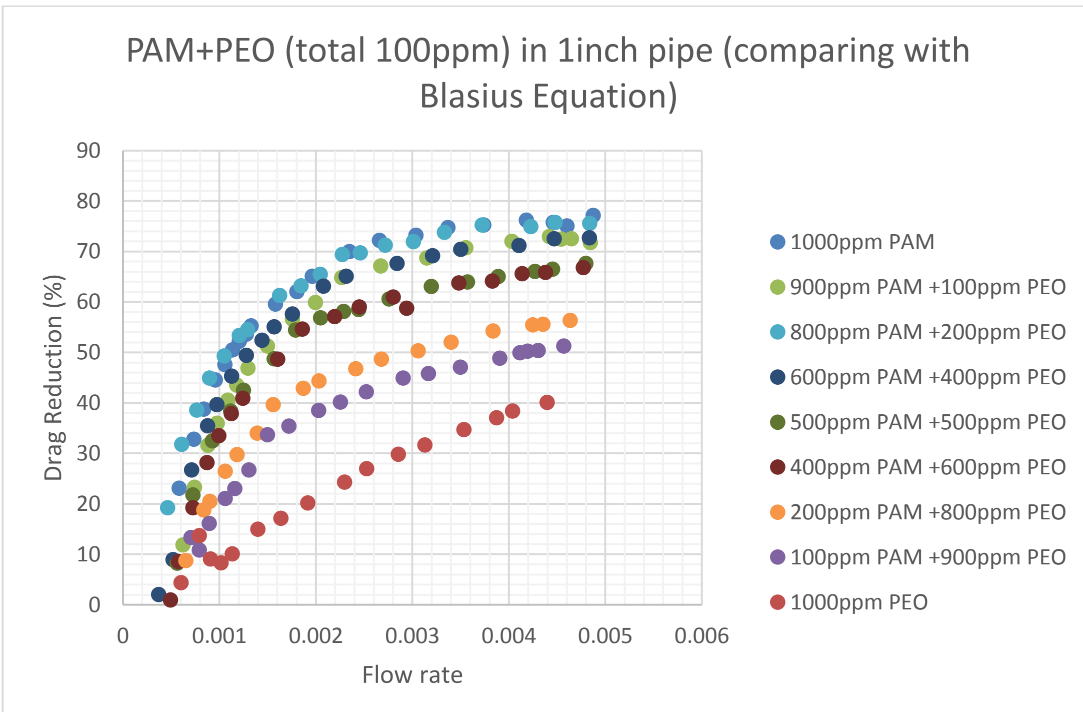


Figure 70 (a)

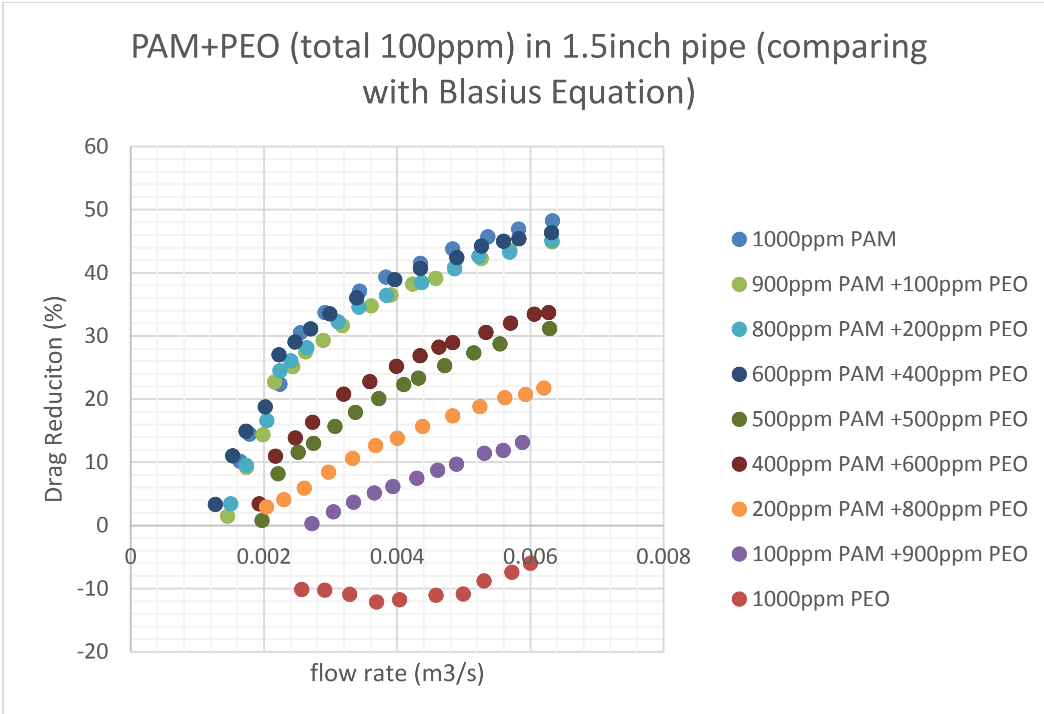


Figure 70 (b)

Figure 70 %DR of PAM+PEO (total 10000ppm) in Pipelines (comparing with Blasius Equation)

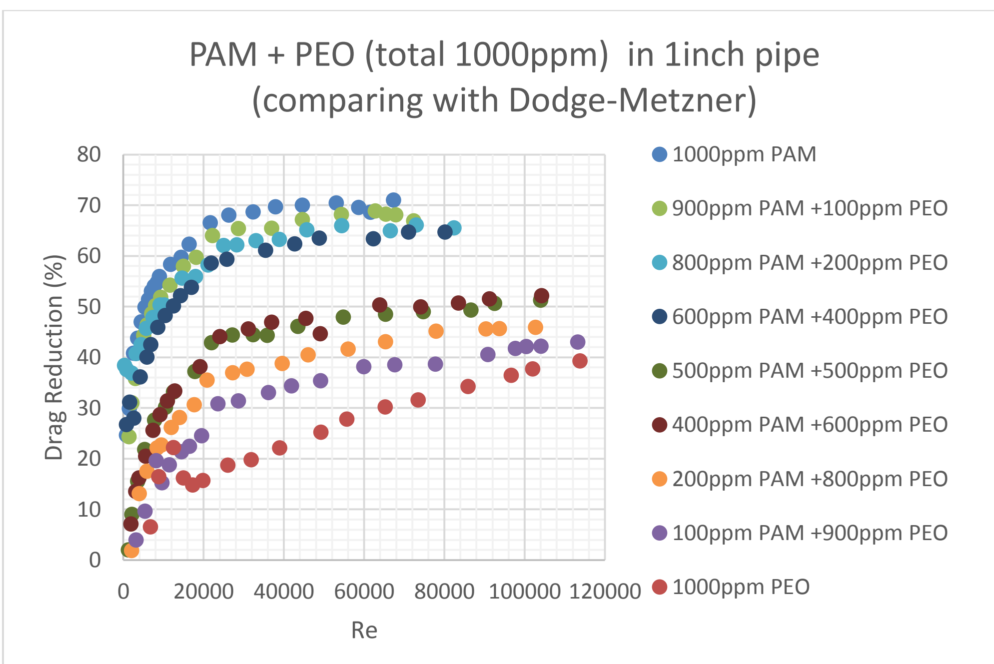


Figure 71 (a)

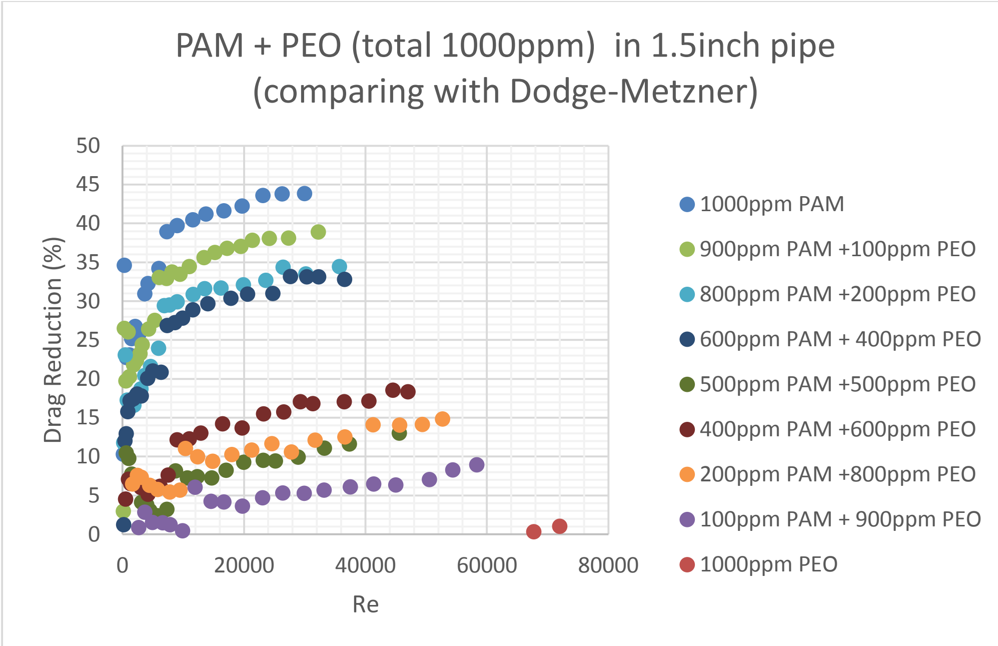


Figure 71 (b)

Figure 71 %DR of PAM+PEO (total 10000ppm) in Pipelines (comparing with Dodge- Metzner Equation)

6.3 Conclusion

According to literature review, it said that PAM unit is a very weak proton donor, not capable forming a complex with PEO. While based on the investigations by our research, some interactions should occur in PAM/PEO system especially when PEO fraction is high.

- Surface tension results indicate 10% PEO fraction is very important. Before this point, the values of surface tension drop from 70dync/cm to 61 dyne/cm sharply, accompanied with a slight increase later. While, no obvious changes in pipeline behavior can be found.
- The results of %DR describe PAM is a better DR donor than PEO. %DR in high PAM concentration are much higher than PEO domain solutions.
- Same results are presented by comparing with Blasius Equation and Dodge-Metzner Equation. However the %DR contrasted to Newtonian fluids are much higher than those compared with Non-Newtonian fluid.

- Both shear viscosity and pipeline behavior indicate that a new type of interactions occur when PEO fraction is higher than 50%. This interaction can prevent polymer-polymer complexex from fully stretching and attaching onto the inner surface of pipeline, which can contribute to smaller hydrodynamic radius of polymer coils. By this reason, DR ability decreases.
- High polymer concentration has no effect on n values. But for k values, 1000ppm solutions present larger k values than 500ppm solutions. In our experiments, %DR go down with the increase of n values and the decrease of K values.
- The interactions between PEO and PAM result in earlier onset point, which means a tiny amount of PAM addition in PEO solution can produce DR ability at lower turbulent conditions (lower Reynolds number). This also has been reported by Mevawalla.

Chapter 7
Overall Conclusions and Recommendations

7.1 Conclusions

- Carboxyl methyl cellulose (CMC) is a great drag-reducer, it can produce a high DR ability in the range of our experiments.
- Polymer concentration has no effect on the onset of DR. As for the tested CMC/surfactant systems, extra concentrations of Aromox (over PSP) have a positive effect on advancing the onset points.
- Obvious distinctions in shear viscosity versus shear rate plots indicate strong the occurrence of strong interactions (CMC-Stepanol, CMC-Stepwet, CMC-Amphosol)
- CMC solutions and CMC-Surfactant solutions we measured are all shear-thinning solutions. With the increase of shear rate, shear viscosities decrease gradually.
- Alfonic 1412-3 and Alfonic 1412-9 have the same interaction process (increase a little at low surfactant concentration and then decrease), which is because: 1. the addition of surfactant makes it change from Type A to Type B drag reduction behavior, this will lower the total %DR 2. Because the hydrophobic interaction is weak, at low surfactant concentrations, surfactants are able to bind onto polymer chains. The increase in DR results from the independent effects from polymer and surfactant solely. When surfactant concentration is high, the binding effect of surfactant protects polymer from stretching which leads to the deduction. By estimation, CMC-Stepanol and CMC-Stepwet also follows the same mechanism.
- Shear induce structures (SIS) at high turbulent conditions will break up the macromolecular chains of CMC, which will result in a decrease in %DR increasing trend.
- For CMC-Aromox system, free Aromox micelles have significant DR ability which makes the high rise in %DR when surfactant concentration is high.
- Both electrostatic and hydrophobic interactions exist in CMC-Amphosol system. The interactions can break macromolecules and reduce the hydrophobic groups in polymer, which results in a decreasing trend in %DR with the increase of surfactant concentration.

- Diameter effects are found to be important in CMC-Alfonic, CMC-Stepanol and CMC-Stepwet systems
- PAM-PEO system is also shear-thinning solutions.
- The interactions between PAM and PEO affect shear viscosities especially when PEO fraction is high.
- The interactions between PEO and PAM result in earlier onset points, %DR can be achieved at lower Reynolds number.
- The results of %DR of pure polymer concentrations describe PAM is a better DR donor than PEO. %DR in high PAM concentration are much higher than PEO domain solutions.
- High polymer concentration has no effect on n values. But for k values, 1000ppm solutions present larger k values than 500ppm solutions. In our experiments, %DR go down with the increase of n values and the decrease of K values.
- For the whole research, a comparison between Blasius Equation and Dodge-Metzner Equation are presented. Generally, though sometimes the results regarding to different standards are different and even opposite, the overall %DR contrasted to Blasius Equation are relative higher. This is possible because Newtonian fluids have lower friction factors when flowing in pipelines.

7.2 Recommendations for Future Work

- **Higher polymer and surfactant concentration** should be measure to determine whether the interactions between polymer-surfactant, polymer-polymer systems have an effect on critical concentrations, such as CMC, CAC and PSP.
- **Temperature, PH value, the addition of salt** should be taken into account to investigate the factor that may have influence on DR. In our research, the temperature is constant at 25℃, no measurement is conducted on PH value and salt concentration.
- **The exact mechanism of drag reduction by polymer and surfactant**. Although extensive works have been done, several researcher have proposed many theory for DR, the exact mechanism is still not clear. More researches are require to fully understand it via different perspectives.
- **Visualization techniques are needed to monitor the occurrence of interaction as well as the microstructures.** 3D Image Technique and Cryo-TEM can provide us a direct visualization on fluid properties and interactions, which is crucial for us to understand DR process and mechanism.
- **The interactions on DR between non-ionic polymers with addition of zwitterionic surfactants.** Few literatures focus the combination of non-ionic polymer/zwitterionic surfactant system. They are capable to interact with each other via hydrophobic interactions. New investigation will be observed on the flow behaviors on DR.

Appendix A

Physical and Chemical Properties of Materials Used in This Thesis

1. Polymers

PROPERTIES

Typical properties of Aqualon® CMC polymer and in solution and film form are shown in Table III. These are not necessarily specifications.

Table III—Typical Properties of Aqualon CMC

Polymer	
Sodium carboxymethylcellulose— dry basis, %, min	99.5
Moisture content (as packed), %, max	8.0
Browning temperature, °C	227
Charring temperature, °C	252
Bulk density, g/ml	0.75
Biological oxygen demand (BOD)[f], ppm	
7H type	11,000
7L type	17,300
Solutions	
pH, 2% solution	7.5
Surface tension, 1% solution, dynes/cm at 25°C.	71
Specific gravity, 2% solution	1.0068
Refractive index, 2% solution	1.336
Typical Films (Air-Dried)	
Density, g/ml	1.59
Refractive index	1.515
Thermal conductivity, W/mK.	0.238

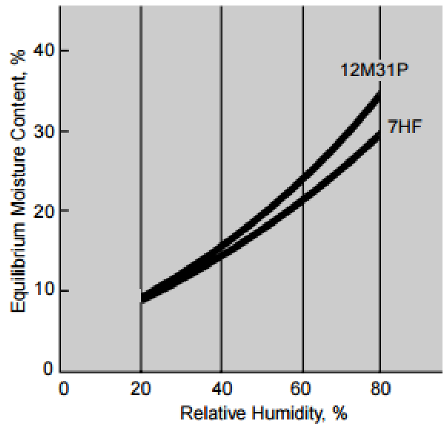
[f]After 5 days' incubation. Under these conditions, cornstarch has a BOD of over 800,000 ppm.

MOISTURE ABSORPTION

CMC absorbs moisture from the air. The amount absorbed and the rate of absorption depend on the initial moisture content and on the relative humidity and temperature of the surrounding air. Figure 3 shows the effect of relative humidity on equilibrium moisture content of three types of Aqualon CMC.

As Aqualon CMC is packed, its moisture content does not exceed 8% by weight. Because of varying storage and shipping conditions, there is a possibility of some moisture pickup from the "as-packed" value.

Figure 3
Effect of Relative Humidity on Equilibrium Moisture Content of Aqualon CMC at 25°C



PHYSIOLOGICAL PROPERTIES

Dermatological and toxicological studies by independent laboratories demonstrate conclusively that sodium carboxymethylcellulose shows no evidence of being toxic to white rats, dogs, guinea pigs, or human beings. Feeding, metabolism, and topical use studies also show that CMC is physiologically inert. Patch tests on human skin demonstrated that sodium carboxymethylcellulose was neither a primary irritant nor a sensitizing agent. Additional information is available from Hercules Incorporated.

DISPERSION AND DISSOLUTION OF CMC

A number of factors such as solvent, choice of polymer, and shear rate affect dispersion and dissolution of CMC.

SOLVENT

Aqualon® CMC is soluble in either hot or cold water. The gum is insoluble in organic solvents, but dissolves in suitable mixtures of water and water-miscible solvents, such as ethanol or acetone. Solutions of low concentration can be made with up to 50% ethanol or 40% acetone. Aqueous solutions of CMC tolerate addition of even higher proportions of acetone or ethanol, the low-viscosity types being considerably more tolerant than the high-viscosity types, as shown below.

Tolerance of Aqualon CMC Solutions for Ethanol

CMC Type	Volume Ratio of Ethanol to CMC Solution, 1%: First Evident Haze	Volume Ratio of Ethanol to CMC Solution, 1%: First Distinct Precipitate
7L	2.4 to 1	3.6 to 1
7M	2.1 to 1	2.7 to 1
7H	1.6 to 1	1.6 to 1

Note: In these tests, ethanol (95%) was added slowly at room temperature to the vigorously stirred 1% CMC solution.

TYPE OF CMC

The higher the degree of substitution, the more rapidly CMC dissolves. The lower the molecular weight, the faster the rate of solution.

Particle size has a pronounced effect on the ease of dispersing and dissolving CMC. "C," or coarse, types were developed to improve dispersibility of the granules when agitation is inadequate to produce a vortex on the liquid surface. Solution time, on the other hand, is extended considerably with a coarse material.

For applications requiring a rapid solution time, CMC of fine particle size (X grind) is best. However, special dissolving techniques, such as prewetting the powder with a nonswelling liquid, mixing it with other dry materials, or using an eductor-type mixing device, are necessary to obtain dispersion.

SHEAR RATE

Preparing solutions by extremely low shear agitation, such as shaking by hand, is generally not recommended. Properties of the resulting solution are quite different from those prepared by higher shear methods. The effect of shear on solution properties is discussed in more detail on pages 11 and 16.

DISPERSION METHODS

CMC particles have a tendency to agglomerate, or lump, when first added to water. To obtain good solutions easily, the dissolving process should be considered a two-step operation:

1. Dispersing the dry powder in water. Individual particles should be wet and the dispersion should not contain lumps.
2. Dissolving the wetted particles.

When the proper technique is used, good dispersion is obtained, and CMC goes into solution rapidly. To prepare lumpfree, clear solutions, a variety of methods can be used:

Method 1
Add CMC to the vortex of vigorously agitated water. The rate of addition must be slow enough to permit the particles to separate and their surfaces to become individually wetted, but it should be fast enough to minimize viscosity buildup of the aqueous phase while the gum is being added.

Method 2
Prior to addition to water, wet the powder with a water-miscible liquid such as alcohol, glycol, or glycerol that will not cause CMC to swell. Two to three parts of liquid per part of CMC should be sufficient.

Method 3
Dry-blend the CMC with any dry, nonpolymeric material used in the formulation. Preferably, the CMC should be less than 20% of the total blend.

Method 4
Use a water eductor (Figure 4) to wet out the polymer particles rapidly. The polymer is fed into a water-jet eductor, where a high-velocity waterflow instantly wets out each particle, thus preventing lumping. This procedure speeds solution preparation and is particularly useful where large volumes of solutions are required. For users wishing the convenience of an automatic system, a polymer solution preparation system (PSP), which is used in conjunction with a water eductor, is shown in Figure 5.

Special, fast-dissolving fluidized polymer suspensions of CMC are available to give very rapid dissolution where it is required or where agitation is substandard.

Users are encouraged to contact their technical representative for information on PSP units or fluidized suspensions of CMC.

2. COMPOSITION INFORMATION

Component	CAS #	Amount (%W/W)
Poly(ethylene oxide)	25322-68-3	>= 95 %
Fumed silica (generic)	112945-52-5	<= 3%
Calcium as mixed salts	Not available	<= 1%
BHT	128-37-0	<= 0.1%
Ammonia	7664-41-7	<= 0.02%
Monoethylamine	75-04-7	<= 0.02%
Ethylene oxide	75-21-8	<= 0.001%

3. HAZARDS IDENTIFICATION

3.1 EMERGENCY OVERVIEW

Appearance White to off-white

Physical State Powder

Odor Ammoniacal

Hazards of product WARNING! CAUSES EYE IRRITATION.
STATIC IGNITION HAZARD CAN RESULT FROM HANDLING AND USE.
DUST DISPERSED IN AIR MAY BE IGNITED AND BURN RAPIDLY.
PLASTIC CONTAINER, IF PRESENT, MAY CAUSE STATIC IGNITION HAZARD.
SLIPPERY WHEN WET.

3.2 POTENTIAL HEALTH EFFECTS

hyperdrill® **AF 207**

ANIONIC DRY SHALE INHIBITOR

DESCRIPTION

HYPERDRILL® AF 207 is a high molecular weight, medium charge, polyacrylamide supplied as a dry granular powder. It has excellent handling characteristics, mixes easily and dissolves quickly when added to water-based fluid systems.

TYPICAL PROPERTIES

Appearance:	White Granular Powder
Ionic Character:	Anionic
Bulk Density:	0.8 gr/cc (50 lbs./cu. ft.)
pH of 0.5% Soln. @ 25°C:	6.0 - 8.0

APPLICATIONS

HYPERDRILL® AF 207 is a very versatile polymer which can be used for oil, gas, water well and mineral drilling. It can be added to fresh, KCL or sea water based drilling fluid systems. **HYPERDRILL® AF 207** functions primarily as a:

- SHALE INHIBITOR
- VISCOSIFIER
- FLOW LINE FLOCCULANT
- FRICTION REDUCER/LUBRICANT
- FOAM STABILIZER

PRINCIPAL FUNCTIONS

Shale Inhibitor

HYPERDRILL® AF 207 can be used alone or in conjunction with KCL to stabilize active shales by decreasing the shale's tendency to absorb water, swell and slough-off. As an additional benefit, fluid loss is often reduced when using this product. The recommended dosage rate is 0.25 - 1.0 ppb as supplied.

Viscosifier

The addition of 0.5 - 1.0 ppb of **HYPERDRILL® AF 207** is a cost effective way to generate viscosity in fresh or low salinity drilling fluids. It's shear thinning capacity assures maximum power at the bit under high shear while retaining excellent carrying capacity under low shear conditions.

Flow Line Flocculant

HYPERDRILL® AF 207 can also be utilized for clear water or low solids drilling. The addition of a 0.5% solution of **HYPERDRILL® AF 207** into the flow line or just prior to any mechanical separation equipment will greatly enhance the removal of drill solids.

Friction Reducer

The addition of **HYPERDRILL® AF 207** into a drilling fluid will help reduce turbulent flow, friction and power losses at points of high shear. Lowering turbulent flow also helps reduce erosion and washouts of fragile geologic structures.

Foam Stabilizer

HYPERDRILL® AF 207 assists in foam drilling by creating a very stable foam, thereby increasing foam life. This results in enhanced cuttings removal and reduced water requirements. The product is compatible with most commonly used foamers.

PACKAGING

HYPERDRILL® AF 207 is supplied in 50 lb. (net), multi-walled, polyethylene-lined, paper bags, packed 30 to a shrink-wrapped pallet or in 1500 lb. (net) bulk bags.

STORAGE

HYPERDRILL® AF 207 should be stored inside under cool dry conditions. When stored under these conditions, the product has a shelf life of at least one year.

HEALTH AND SAFETY

HYPERDRILL® AF 207 exhibits a low order of toxicity. However, precautions should be taken to avoid inhalation, ingestion or contact with skin or eyes. For additional information, see the relevant MSDS.

SPILLS: Polymer spills are extremely slippery and therefore hazardous. They should be addressed immediately. Dry polymer spills should be left dry, swept up and disposed of according to local, state or federal regulations. If the polymer becomes wet, an absorbent material should be applied to the spill, then swept up and discarded. **Do not add water to a spill.**

TDS/207/V2/1-97

hychem, inc. 10014 North Dale Mabry Highway, Suite 213, Tampa, FL 33618 • Tel: (813) 963-6214 • FAX: (813) 960-0175

2. Surfactants

SAFETY DATA SHEET

ALFONIC® 1412-9 Ethoxylate

SECTION 1 IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

Trade name	ALFONIC® 1412-9 Ethoxylate	
Synonyms	Ethoxylated Alcohol, Laureth-9	
Use	Detergent, Mining, Industrial & Institutional cleaning, Surfactant, Emulsifier	
Company	Sasol Chemicals (USA) LLC (an affiliate of Sasol Chemicals North America LLC)	
Address	12120 Wickchester Lane Houston TX 77079	
Telephone	CHEMTREC North America Transportation Emergency (24-hr)	(800) 424-9300
	CHEMTREC World Wide	(703) 527-3887
	Other Emergencies (24-hr)	(337) 494-5142
	MSDS and Product Information (8:00am-4:30pm CST)	(281) 588-3491
	Health and Safety Information (7:30am-4:00pm CST)	(281) 588-3492
E-mail address	SasolElectronicSDS@us.sasol.com	

SECTION 2 HAZARDS IDENTIFICATION

GHS Hazards

Serious eye damage	Category 1
Chronic aquatic toxicity	Category 3

LABEL ELEMENTS

Hazard symbols

Signal word Danger

Hazard statements
H318 Causes serious eye damage.
H412 Harmful to aquatic life with long lasting effects.

Precautionary statements

Prevention
P280 Wear eye protection/ face protection.
P273 Avoid release to the environment.

Response
P305 + P351 + P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/ physician.

Disposal
P501 Dispose of contents/ container to an approved waste disposal plant.

Methods and materials for containment and cleaning up	Evacuate personnel to safe areas. Remove all sources of ignition. Contain spillage, and then collect with non-combustible absorbent material, (e.g. sand, earth, diatomaceous earth, vermiculite) and place in container for disposal according to local / national regulations (see section 13). Do not flush into surface water or sanitary sewer system.

SECTION 7 HANDLING AND STORAGE

Safe handling advice	Take precautionary measures against static discharges.
Storage/Transport pressure	Ambient
Load/Unload temperature	32 - 43 °C 90 - 110 °F
Storage and handling materials	Suitable: Carbon steel coated with baked phenolic. Any moisture may cause rusting of carbon steel. If product is moisture free, uncoated carbon steel tanks.
Further information on storage conditions	When stored in the liquid form, ethoxylates should be padded with a dry inert gas, such as nitrogen, to prevent oxygen or air from entering the tank. Prolonged storage in the presence of air or oxygen may cause product degradation. Oxidation is not expected when stored under a nitrogen atmosphere. Inert gas blanket and breathing system needed to maintain color stability. Use dry inert gas having at least -40°C (-40°F) dew point.

SECTION 8 EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING MEASURES

Ensure adequate ventilation, especially in confined areas. Trace amounts of ethylene oxide may be present in the product and could accumulate in vapor spaces of storage or transport vessels.

PERSONAL PROTECTIVE EQUIPMENT

Eyes	Wear as appropriate: Goggles, Face-shield
Skin	Full protective clothing, chemical boots, and chemical gloves. High standards of skin care and personal hygiene should be exercised at all times.
Inhalation	Use respirator when performing operations involving potential exposure to vapour of the product. Use NIOSH approved respiratory protection.

EXPOSURE GUIDELINES

There are no exposure limits established for this product. Trace amounts of ethylene oxide may be present in this product., The ethylene oxide in this product is not expected to result in significant exposures or present a health hazard.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Appearance solid; colorless liquid when melted;

Colour	white
Form	solid
Odour	sweet pungent
Odour Threshold	no data available
Flash point	171 °C, 340 °F; PM;
Flammability	Upper explosion limit: approximately 0.8 %(V)
	Lower explosion limit: approximately 0.1 %(V)
Boiling point/boiling range	174 - 331 °C, 346 - 628 °F;
Melting point/range	20 - 25 °C, 68 - 77 °F;
Auto-ignition temperature	358 °C, 676 °F;
Decomposition temperature	no data available
Flammability (solid, gas)	no data available
Vapour pressure	0.18 psi @ 38 °C, 100 °F;
Vapour density	20 - 22
Density	0.995 g/cm3 @ 22 °C, 71 °F;
Specific gravity	no data available
Water solubility	soluble
Viscosity	43.1 cSt @ 38 °C, 100 °F;
pH	6 - 8
Evaporation rate	no data available
Partition coefficient: n-octanol/water	no data available

SECTION 10 STABILITY AND REACTIVITY

Reactivity	Stable at normal ambient temperature and pressure.
Chemical stability	No decomposition if stored and applied as directed.

SAFETY DATA SHEET

ALFONIC® 1412-3 Ethoxylate

SECTION 1 IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

Trade name ALFONIC® 1412-3 Ethoxylate

Synonyms Ethoxylated Alcohol, Laureth-3

Use Detergent, Industrial use

Company Sasol Chemicals (USA) LLC
(an affiliate of Sasol Chemicals North America LLC)

Address 12120 Wickchester Lane Houston TX 77079

Telephone	CHEMTREC North America Transportation Emergency (24-hr)	(800) 424-9300
	CHEMTREC World Wide	(703) 527-3887
	Other Emergencies (24-hr)	(337) 494-5142
	MSDS and Product Information (8:00am-4:30pm CST)	(281) 588-3491
	Health and Safety Information (7:30am-4:00pm CST)	(281) 588-3492

E-mail address SasolElectronicSDS@us.sasol.com

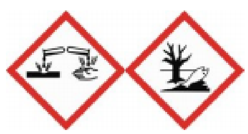
SECTION 2 HAZARDS IDENTIFICATION

GHS Hazards

Serious eye damage	Category 1
Acute aquatic toxicity	Category 1
Chronic aquatic toxicity	Category 3

LABEL ELEMENTS

Hazard symbols



Signal word Danger

Hazard statements
H318 Causes serious eye damage.
H400 Very toxic to aquatic life.
H412 Harmful to aquatic life with long lasting effects.

Precautionary statements

Prevention
P280 Wear eye protection/ face protection.
P273 Avoid release to the environment.

Response
P305 + P351 + P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/ physician.

Methods and materials for containment and cleaning up	Evacuate personnel to safe areas. Remove all sources of ignition. Contain spillage, and then collect with non-combustible absorbent material, (e.g. sand, earth, diatomaceous earth, vermiculite) and place in container for disposal according to local / national regulations (see section 13). Do not flush into surface water or sanitary sewer system.

SECTION 7 HANDLING AND STORAGE

Safe handling advice	Take precautionary measures against static discharges.
Storage/Transport pressure	Ambient
Load/Unload temperature	24 - 38 °C 75 - 100 °F
Storage and handling materials	Suitable: Carbon steel coated with baked phenolic. Any moisture may cause rusting of carbon steel. If product is moisture free, uncoated carbon steel tanks.
Further information on storage conditions	When stored in the liquid form, ethoxylates should be padded with a dry inert gas, such as nitrogen, to prevent oxygen or air from entering the tank. Prolonged storage in the presence of air or oxygen may cause product degradation. Oxidation is not expected when stored under a nitrogen atmosphere. Inert gas blanket and breathing system needed to maintain color stability. Use dry inert gas having at least -40°C (-40°F) dew point.

SECTION 8 EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING MEASURES

Ensure adequate ventilation, especially in confined areas. Trace amounts of ethylene oxide may be present in the product and could accumulate in vapor spaces of storage or transport vessels.

PERSONAL PROTECTIVE EQUIPMENT

Eyes	Wear as appropriate: Goggles, Face-shield
Skin	Full protective clothing, chemical boots, and chemical gloves. High standards of skin care and personal hygiene should be exercised at all times.
Inhalation	Use respirator when performing operations involving potential exposure to vapour of the product. Use NIOSH approved respiratory protection.

EXPOSURE GUIDELINES

There are no exposure limits established for this product. Trace amounts of ethylene oxide may be present in this product., The ethylene oxide in this product is not expected to result in significant exposures or present a health hazard.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Appearance	liquid;

ALFONIC® 1412-3 Ethoxylate

Colour	Clear, colorless
Form	liquid
Odour	sweet pungent
Odour Threshold	no data available
Flash point	161 °C, 322 °F; PM;
Flammability	Upper explosion limit: approximately 1.2 %(V)
	Lower explosion limit: approximately 0.2 %(V)
Boiling point/boiling range	119 °C, 246 °F;
Melting point/range	8 - 13 °C, 46 - 56 °F;
Auto-ignition temperature	237 °C, 459 °F;
Decomposition temperature	no data available
Flammability (solid, gas)	no data available
Vapour pressure	< 0.1 psi @ 38 °C, 100 °F;
Vapour density	10 - 12
Density	0.918 g/cm3 @ 22 °C, 72 °F;
Specific gravity	no data available
Water solubility	Dispersible
Viscosity	52 cSt 20 cSt @ 21 °C, 70 °F;
pH	6.9
Evaporation rate	no data available
Partition coefficient: n-octanol/water	no data available

SECTION 10 STABILITY AND REACTIVITY

Reactivity	Stable at normal ambient temperature and pressure.
Chemical stability	No decomposition if stored and applied as directed.

Aromox® DMC

CASRN: 61788-90-7
Dimethylcocoalkylamine Oxides

Dimethylcocoalkylamine oxides

Specification

Parameter	Limits	Method
Amine Oxide	39 - 43 %	
Amine	1.5 % max	
Peroxide	0.34 % max	

Typical Data

Chemical and Physical Data	Typical Value
HLB value	22 Davies Scale 0-40
Vapour pressure	< 22 mm Hg @20 C
Viscosity	18 SSU
Pour point	-32 C
Flash point	21 C
Melting point	-36 C
Appearance	Liquid at 25°C
Equivalent Mass	224
Specific Gravity	0.890(25), 0.868(40), 0.852(60)

Typical Data are based on our own measurements or derived from the literature. They do not constitute part of the delivery specification.

Version: 4.0   Issued: 17 January 2014 - North America

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Asia/Pacific: Shanghai, China, T: +86 21 2220 5000, e: surfactants.asia@akzonobel.com
www.akzonobel.com/sc

Stepan

SAFETY DATA SHEET

1. Identification

Product identifier	**STEPANOL WA-100 NF/USP**
Other means of identification	
Product code	0620
Recommended use	Surfactant
Recommended restrictions	For industrial use only.

Manufacturer/Importer/Supplier/Distributor information

Manufacturer

Company name	Stepan Company	
Address	22 West Frontage Road Northfield, IL 60093 USA	
Telephone	General	1-847-446-7500
E-mail	Not available.	
Emergency phone number	Medical	1-800-228-5635
	Chemtrec	1-800-424-9300
	Chemtrec Int'l	+1 703-527-3887

2. Hazard(s) identification

Physical hazards	Not classified.	
Health hazards	Acute toxicity, oral	Category 4
	Skin corrosion/irritation	Category 2
	Serious eye damage/eye irritation	Category 1
Environmental hazards	Hazardous to the aquatic environment, acute hazard	Category 2
	Hazardous to the aquatic environment, long-term hazard	Category 3
OSHA defined hazards	Combustible dust	Classified

Label elements

Signal word Danger

Hazard statement Harmful if swallowed. May be harmful in contact with skin. Causes skin irritation. Causes serious eye damage. Toxic to aquatic life. Harmful to aquatic life with long lasting effects.

Prevention Wash thoroughly after handling. Do not eat, drink or smoke when using this product. Avoid release to the environment. Wear protective gloves. Wear eye/face protection.

Response If swallowed: Call a poison center/doctor if you feel unwell. If on skin: Wash with plenty of water. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center/doctor. Specific treatment (see this label). Rinse mouth. If skin irritation occurs: Get medical advice/attention. Take off contaminated clothing and wash before reuse.

Storage Store away from incompatible materials.

Disposal Dispose of contents/container in accordance with local/regional/national/international regulations.

Hazard(s) not otherwise classified (HNOC) Product may form explosive dust/air mixture if high concentration of product dust is suspended in air.

Supplemental information None.

3. Composition/information on ingredients

Mixtures

Chemical name	Common name and synonyms	CAS number	%
Sodium Lauryl Sulfate (Alt Cas 68585-47-7)		151-21-3	90 - 100

8. Exposure controls/personal protection

Occupational exposure limits	No exposure limits noted for ingredient(s).
Biological limit values	No biological exposure limits noted for the ingredient(s).
Appropriate engineering controls	Good general ventilation (typically 10 air changes per hour) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level. Ventilation should be sufficient to effectively remove and prevent buildup of any dusts or fumes that may be generated during handling or thermal processing. Eye wash facilities and emergency shower must be available when handling this product.
Individual protection measures, such as personal protective equipment	
Eye/face protection	Wear eye/face protection. Use tight fitting goggles if dust is generated.
Hand protection	Wear appropriate chemical resistant gloves.
Skin protection	
Other	Wear appropriate chemical resistant clothing.
Respiratory protection	Use a NIOSH/MSHA approved respirator if there is a risk of exposure to dust/fume at levels exceeding the exposure limits.
Thermal hazards	Wear appropriate thermal protective clothing, when necessary.
General hygiene considerations	When using, do not eat, drink or smoke. Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants.

9. Physical and chemical properties

Appearance	
Physical state	Solid.
Form	Powder. Class II Dust for National Electric Code (NFPA 70) Pmax = 7.8bar Kst = 196 bar m/s Minimum Ignition Energy (MIE) = 10 - 30 (estimated 12) mJ Minimum Explosible Concentration (MEC) = 37 g/m3 Minimum Autoignition Temperature (MAIT Cloud) = 260 C Limiting Oxygen Concentration (LOC) = 12.2 vol. % Mean particle size = 155 (17% < 75) micrometer
Color	White.
Odor	Not available.
Odor threshold	Not available.
pH	9.7500 (@ 1% Aqueous)
Melting point/freezing point	Not available.
Initial boiling point and boiling range	Not available.
Flash point	Not available.
Evaporation rate	Not applicable.
Flammability (solid, gas)	Not available.
Upper/lower flammability or explosive limits	
Flammability limit - upper (%)	NOT DETERMINED.
Explosive limit - lower (%)	Not available.
Explosive limit - upper (%)	Not available.
Vapor pressure	Not available.
Vapor density	Not applicable. Powder.
Relative density	Not available.
Solubility(ies)	
Solubility (water)	Not available.
Auto-ignition temperature	Not available.
Decomposition temperature	Not available.
Viscosity	Not available.
Other information	
Percent volatile	0

Stepan

SAFETY DATA SHEET

1. Identification

Product identifier STEPWET DF-95

Other means of identification

Product code 0615

Recommended use Surfactant

Recommended restrictions For industrial use only.

Manufacturer/Importer/Supplier/Distributor information

Manufacturer

Company name Stepan Company

Address 22 West Frontage Road
Northfield, IL 60093
USA

Telephone	General	1-847-446-7500
E-mail	Not available.	
Emergency phone number	Medical	1-800-228-5635
	Chemtrec	1-800-424-9300
	Chemtrec Int'l	+1 703-527-3887

2. Hazard(s) identification

Physical hazards	Not classified.	
Health hazards	Acute toxicity, oral	Category 4
	Skin corrosion/irritation	Category 2
	Serious eye damage/eye irritation	Category 1
Environmental hazards	Hazardous to the aquatic environment, acute hazard	Category 2
	Hazardous to the aquatic environment, long-term hazard	Category 3
OSHA defined hazards	Combustible dust	Classified

Label elements

Signal word Danger

Hazard statement Harmful if swallowed. May be harmful in contact with skin. Causes skin irritation. Causes serious eye damage. Toxic to aquatic life. Harmful to aquatic life with long lasting effects.

Prevention Wash thoroughly after handling. Do not eat, drink or smoke when using this product. Avoid release to the environment. Wear protective gloves. Wear eye/face protection.

Response If swallowed: Call a poison center/doctor if you feel unwell. If on skin: Wash with plenty of water. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center/doctor. Specific treatment (see this label). Rinse mouth. If skin irritation occurs: Get medical advice/attention. Take off contaminated clothing and wash before reuse.

Storage Store away from incompatible materials.

Disposal Dispose of contents/container in accordance with local/regional/national/international regulations.

Hazard(s) not otherwise classified (HNOC) Product may form explosive dust/air mixture if high concentration of product dust is suspended in air.

Supplemental information None.

3. Composition/information on ingredients

Mixtures

Chemical name	Common name and synonyms	CAS number	%
Sodium Lauryl Sulfate (Alt. CAS 73296-89-6, 68585-47-7)		151-21-3	90 - 100

Chemical name	Common name and synonyms	CAS number	%
Lauryl alcohol		112-53-8	1 - < 3
Sodium sulfate		7757-82-6	< 3.5
Sodium chloride		7647-14-5	< 2
Water		7732-18-5	< 2

4. First-aid measures

Inhalation
If dust from the material is inhaled, remove the affected person immediately to fresh air. Call a physician if symptoms develop or persist.

Skin contact
Wash with plenty of soap and water. Call a POISON CENTER or doctor/physician if you feel unwell. If skin irritation occurs: Get medical advice/attention. Take off contaminated clothing and wash before reuse.

Eye contact
Immediately flush eyes with plenty of water for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Get medical attention immediately.

Ingestion
Rinse mouth. IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.

Most important symptoms/effects, acute and delayed
Symptoms may include stinging, tearing, redness, swelling, and blurred vision. Permanent eye damage including blindness could result. Skin irritation. May cause redness and pain.

Indication of immediate medical attention and special treatment needed
Provide general supportive measures and treat symptomatically. In case of shortness of breath, give oxygen. Keep victim warm. Keep victim under observation. Symptoms may be delayed.

General information
In the case of accident or if you feel unwell, seek medical advice immediately (show the label where possible). Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves.

5. Fire-fighting measures

Suitable extinguishing media
Water spray. Water fog. Foam. Dry chemical powder. Carbon dioxide (CO_2). Apply extinguishing media carefully to avoid creating airborne dust.

Unsuitable extinguishing media
None known.

Specific hazards arising from the chemical
Class II Dust for National Electric Code (NFPA 70) Explosion hazard: Avoid generating dust; fine dust dispersed in air in sufficient concentrations and in the presence of an ignition source is a potential dust explosion hazard. During fire, gases hazardous to health may be formed.

Special protective equipment and precautions for firefighters
Self-contained breathing apparatus and full protective clothing must be worn in case of fire.

Fire-fighting equipment/instructions
In case of fire and/or explosion do not breathe fumes. In the event of fire, cool tanks with water spray. Move containers from fire area if you can do so without risk.

Specific methods
Cool containers exposed to flames with water until well after the fire is out.

General fire hazards
May form combustible dust concentrations in air.

6. Accidental release measures

Personal precautions, protective equipment and emergency procedures
Keep unnecessary personnel away. Keep people away from and upwind of spill/leak. Keep out of low areas. Use a NIOSH/MSHA approved respirator if there is a risk of exposure to dust/fume at levels exceeding the exposure limits. Wear appropriate protective equipment and clothing during clean-up. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Avoid inhalation of dust from the spilled material. Ensure adequate ventilation. Local authorities should be advised if significant spillages cannot be contained. For personal protection, see section 8 of the SDS.

Methods and materials for containment and cleaning up
Collect spillage. If sweeping of a contaminated area is necessary use a dust suppressant agent which does not react with the product. Sweep up or vacuum up spillage and collect in suitable container for disposal. Collect dust using a vacuum cleaner equipped with HEPA filter. Minimize dust generation and accumulation. Prevent entry into waterways, sewer, basements or confined areas. Following product recovery, flush area with water. For waste disposal, see section 13 of the SDS.

Environmental precautions
Avoid release to the environment. Contact local authorities in case of spillage to drain/aquatic environment. Prevent further leakage or spillage if safe to do so. Do not contaminate water. Avoid discharge into drains, water courses or onto the ground.

9. Physical and chemical properties

Appearance	
Physical state	Solid.
Form	Powder. Class II Dust for National Electric Code (NFPA 70)
Color	White.
Odor	Not available.
Odor threshold	Not available.
pH	8.5000 - 11.0000 (1% Aqueous)
Melting point/freezing point	Not available.
Initial boiling point and boiling range	> 212 °F (> 100 °C)
Flash point	Not Applicable
Evaporation rate	Estimated slower than ethyl ether.
Flammability (solid, gas)	Not available.
Upper/lower flammability or explosive limits	
Flammability limit - lower (%)	NOT APPLICABLE.
Flammability limit - upper (%)	NOT APPLICABLE.
Explosive limit - lower (%)	Not available.
Explosive limit - upper (%)	Not available.
Vapor pressure	Not Determined or Unknown
Vapor density	Estimated lighter than air.
Relative density	Not available.
Solubility(ies)	
Solubility (water)	Not available.
Auto-ignition temperature	Not available.
Decomposition temperature	Not available.
Viscosity	Not available.
Other information	
Pmax	7.7 bar +/- 10%
Kst	203 bar.m/s +/- 10%
Minimum explosible concentration (MEC)	30 g/m³
Particle size	18 µm (mean)
Specific gravity	0.4800

10. Stability and reactivity

Reactivity	The product is stable and non-reactive under normal conditions of use, storage and transport.
Chemical stability	Material is stable under normal conditions.
Possibility of hazardous reactions	No dangerous reaction known under conditions of normal use.
Conditions to avoid	Contact with incompatible materials. Avoid dispersal of dust in the air (i.e., clearing dust surfaces with compressed air).
Incompatible materials	Strong oxidizing agents.
Hazardous decomposition products	No hazardous decomposition products are known.

Stepan

SAFETY DATA SHEET

1. Identification

Product identifier AMPHOSOL CG

Other means of identification

Product code 0211

Recommended use Surfactant

Recommended restrictions For industrial use only.

Manufacturer/Importer/Supplier/Distributor information

Manufacturer

Company name Stepan Company

Address 22 West Frontage Road
Northfield, IL 60093
USA

Telephone General 1-847-446-7500

E-mail Not available.

Emergency phone number Medical 1-800-228-5635
Chemtrec 1-800-424-9300
Chemtrec Int'l +1 703-527-3887

2. Hazard(s) identification

Physical hazards Not classified.

Health hazards Serious eye damage/eye irritation — Category 1

Environmental hazards Hazardous to the aquatic environment, acute hazard — Category 2

Hazardous to the aquatic environment, long-term hazard — Category 3

OSHA defined hazards Not classified.

Label elements

Signal word Danger

Hazard statement Causes serious eye damage. Toxic to aquatic life. Harmful to aquatic life with long lasting effects.

Prevention Avoid release to the environment. Wear eye/face protection.

Response If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center/doctor.

Storage Store away from incompatible materials.

Disposal Dispose of contents/container in accordance with local/regional/national/international regulations.

Hazard(s) not otherwise classified (HNOC) None known.

Supplemental information None.

3. Composition/information on ingredients

Mixtures

Chemical name	Common name and synonyms	CAS number	%
Water		7732-18-5	63 - < 66
Cocamidopropyl betaine		61789-40-0	29 - < 31
Sodium chloride		7647-14-5	4 - < 6
Glycerin		56-81-5	0 - < 3

4. First-aid measures

Inhalation Move to fresh air. Call a physician if symptoms develop or persist.

Appropriate engineering controls	Good general ventilation (typically 10 air changes per hour) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level. Provide eyewash station. Eye wash facilities and emergency shower must be available when handling this product.

Individual protection measures, such as personal protective equipment

Eye/face protection	Wear safety glasses with side shields (or goggles) and a face shield.
Hand protection	Wear protective gloves.
Skin protection	
Other	Wear appropriate chemical resistant clothing.
Respiratory protection	In case of insufficient ventilation, wear suitable respiratory equipment.
Thermal hazards	Wear appropriate thermal protective clothing, when necessary.
General hygiene considerations	Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants.

9. Physical and chemical properties

Appearance	
Physical state	Liquid.
Form	Liquid.
Color	Not available.
Odor	Not available.
Odor threshold	Not available.
pH	4.0000 - 6.0000 (as is)
Melting point/freezing point	Not available.
Initial boiling point and boiling range	212 °F (100 °C)
Flash point	> 201 °F (> 93.9 °C) PMCC
Evaporation rate	Estimated slower than ethyl ether.
Flammability (solid, gas)	Not available.
Upper/lower flammability or explosive limits	
Flammability limit - upper (%)	NOT APPLICABLE.
Explosive limit - lower (%)	Not available.
Explosive limit - upper (%)	Not available.
Vapor pressure	Not Determined or Unknown
Vapor density	Not available.
Relative density	Not available.
Solubility(ies)	
Solubility (water)	Not available.
Auto-ignition temperature	Not available.
Decomposition temperature	Not available.
Viscosity	14 cps @ 25 C
Other information	
Percent volatile	63 - 67 %
Pour point	26.6 °F (-3 °C)
Specific gravity	1.0576

10. Stability and reactivity

Reactivity	The product is stable and non-reactive under normal conditions of use, storage and transport.
Chemical stability	Material is stable under normal conditions.
Possibility of hazardous reactions	No dangerous reaction known under conditions of normal use.
Conditions to avoid	Avoid temperatures exceeding the flash point. Contact with incompatible materials.
Incompatible materials	Strong oxidizing agents.

Appendix B

Apparatus Specification

1. Thermo Scientific Orion 3-Star Plus Conductivity Meters

The Thermo Scientific Orion 3-Star Plus conductivity meters work for a variety of applications and liquid purities.

Product Specifications

Thermo Scientific Orion 3-Star Plus

Conductivity Meters

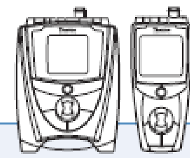
Features and Benefits

- Simultaneous display of conductivity, resistivity, TDS or salinity and temperature measurements on the backlit LCD
- The Thermo Scientific Orion SMART STABILITY™ and SMART AVERAGING™ functions for automatically optimized accuracy, precision and response time
- Meet all U.S. Pharmacopeia (USP) requirements
- Accept cell constants from 0.001 to 199.9 cm^{-1}
- Compatible with 2-electrode and 4-electrode conductivity cells
- Temperature calibration capability
- Conductivity / TDS / salinity / resistivity calibration of up to 5 points
- Reading reference temperatures at 5 °C, 10 °C, 15 °C, 20 °C or 25 °C
- Storage of up to 10 individually password-protected methods for easy retrieval of operation procedures
- Datalog up to 1000 points with time and date stamp
- RS232 port for easy data downloading and software updates
- Benchtop units can control an autosampler and the 096010 stirrer probe (*each sold separately*)
- Benchtop units are splashproof with an IP54-rated housing and include a universal power supply
- Portable units are waterproof with an IP67-rated housing and run for over 2,000 hours on four AA batteries
- 3 year meter warranty

Part of Thermo Fisher Scientific

Thermo SCIENTIFIC

Thermo Scientific Orion 3-Star Plus Conductivity Meters



Conductivity	Range	0.000 to 3000 mS/cm, auto resolution with cell constant dependence
	Resolution	4 significant digits down to 0.001 µS/cm, cell constant dependent
	Relative Accuracy	0.5% ± 1 digit or 0.01 µS/cm, whichever is greater
	Cell Constants	0.001 to 199.9
Resistivity	Range	0.0001 to 100 Megohm
	Resolution	Automatic
	Relative Accuracy	0.5 % ± 1 digit
Salinity	Range	0.1 to 80.0 ppt NaCl equivalent, 0.1 to 42 ppt practical salinity
	Resolution	0.1
	Relative Accuracy	± 0.1 ± 1 digit
TDS	Range	0 to 19999
	Resolution	1 mg/L
	Relative Accuracy	± 0.5 % ± 1 digit
Temperature	Range	- 5 to 105 °C
	Resolution	0.1 up to 99.9 °C, 1.0 over 99.9 °C
	Relative Accuracy	± 0.1 °C

Meters Only

Cat. No.	**Package**
1114000	Includes benchtop meter, universal power and user guide
1214000	Includes portable meter, batteries and user guide

Benchtop Meter Kits

Cat. No. / *Application*	**Sensor (s)**	**Accessories and Solutions**
1114001 / *Fresh Water Wastewater*	• 013005MD DuraProbe conductivity cell, K = 0.475, 1 µS/cm to 200 mS/cm	• 1413 µS/cm conductivity standard (5 x 60 mL bottles) • Swing arm electrode stand
1114002 / *Ultra Pure Water*	• 013016MD Conductivity cell, K = 0.1, includes flow cell, 0.01 µS/cm to 300 µS/cm	• 100 µS/cm conductivity standard (5 x 60 mL bottles) • Swing arm electrode stand
1114003 / *Ultra Pure Water*	• 013016MD Conductivity cell, K = 0.1, includes flow cell, 0.01 µS/cm to 300 µS/cm	• 100 µS/cm conductivity standard (5 x 60 mL bottles) • Conductivity calibration resistor kit • Star Navigator 21 software with RS232 computer cable • Swing arm electrode stand

Portable Meter Kits

Cat. No. / *Application*	**Sensor (s)**	**Accessories and Solutions**
1214001 / *Fresh Water Wastewater*	• 013005MD DuraProbe conductivity cell, K = 0.475, 1 µS/cm to 200 mS/cm	• 1413 µS/cm conductivity standard (10 x 15 mL pouches) • Hard field case
1214002 / *Ultra Pure Water*	• 013016MD Conductivity cell, K = 0.1, includes flow cell, 0.01 µS/cm to 300 µS/cm	• 100 µS/cm conductivity standard (5 x 60 mL bottles)
1214003 / *Fresh Water Wastewater*	• 013610MD Conductivity cell, K = 0.55, includes 3 meter cable, 10 µS/cm to 200 mS/cm)	• 1413 µS/cm conductivity standard (10 x 15 mL pouches) • Hard field case
1214004 / *Ultra Pure Water*	• 013016MD Conductivity cell, K = 0.1, includes flow cell, 0.01 µS/cm to 300 µS/cm	• 100 µS/cm conductivity standard (5 x 60 mL bottles) • Hard field case
1214501 / *Fresh Water Wastewater*	• 013005MD DuraProbe conductivity cell, K = 0.475, 1 µS/cm to 200 mS/cm	• 1413 µS/cm conductivity standard (10 x 15 mL pouches) • Soft field case
1214503 / *Fresh Water Wastewater*	• 013610MD DuraProbe conductivity cell, K = 0.55, includes 3 meter cable, 10 µS/cm to 200 mS/cm	• 1413 µS/cm conductivity standard (10 x 15 mL pouches) • Soft field case
1214504 / *Ultra Pure Water*	• 013016MD Conductivity cell, K = 0.1, includes flow cell, 0.01 µS/cm to 300 µS/cm	• 100 µS/cm conductivity standard (5 x 60 mL bottles) • Soft field case
1214101 / *Fresh Water Wastewater*	• 013005MD DuraProbe conductivity cell, K = 0.475, 1 µS/cm to 200 mS/cm	—

S-3STARCD-E 0408 RevA

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Thermo SCIENTIFIC

2. FANN Model 35 Viscometer

fann

Product Information **Oil Well Cements**

Model 35A/SR12 Viscometer

"The Standard of the Industry"

Fann Model 35A/SR12 Viscometers are true *Couette* coaxial cylinder rotational viscometers. With this type of viscometer the sample is confined between two concentric cylinders, one of which, the rotor, is rotated at a constant velocity. The rotation is the rotor in the presence of the sample produces a torque that is measured at the wall of the inner cylinder. The cylinder radii are such that the sample is homogeneous and the shear-stress is as uniform as possible across the gap.

FANN Direct Indicating Viscometers are powered by a motor with a speed reduction gear box. The outer cylinder is driven at a constant rotational velocity for each RPM setting. The rotation of the sleeve on the cement slurry produces a torque on the inner cylinder which is also transmitted to the bob. A torsion spring restrains the movement of the bob and a dial attached to the torsion spring indicates the displacement of the bob.

Twelve total test speeds of 0.9, 1.8, 3, 6, 30, 60, 90, 100, 180, 200, 300, and 600 RPM allow for measurement over an extended shear-rate range in accordance with ***API Recommended Practice 10B***.

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MEASURING RANGE

Model 35 Direct Indicating Viscometer

ROTOR-BOB	R1 B1	R2 B1	R3 B1	R1 B2	R1 B3	R1 B4
BASIC DATA						
Rotor Radius, R_o, cm	1.8415	1.7588	2.5866	1.8415	1.8415	1.8415
Bob Radius, R_i, cm	1.7245	1.7245	1.7245	1.2276	0.8622	0.8622
Bob Height, L, cm	**3.800**	**3.800**	**3.800**	**3.800**	**3.800**	**1.900**
Shear Gap, in Annulus, cm	**0.1170**	**0.0343**	**0.8261**	**0.6139**	**0.9793**	**0.9793**
Radii Ratio, R_i / R_o	0.9365	0.9805	0.667	0.666	0.468	0.468
Maximum Use Temperature, °C (°F)	93 (200)	93 (200)	93 (200)	93 (200)	93 (200)	93 (200)
Minimum Use Temperature, °C (°F)	**0 (32)**	**0 (32)**	**0 (32)**	**0 (32)**	**0 (32)**	**0 (32)**
Overall Instrument Constant, K	**300.0**	**94.18**	**1355**	**2672**	**7620**	**15,200**
Standard F1 Torsion Spring $\eta = Kf\theta/N$						
SHEAR STRESS RANGE						
Shear Stress Constant for Effective Bob Surface k_2, cm^{-3}	0.01323	0.01323	0.01323	0.0261	0.0529	0.106
Shear Stress Range, dynes/cm² $\gamma = k_1k_2\theta$						
F 0.2 θ = 1°	1.02	1.02	1.02	2.01	4.1	8.2
F 0.2 θ = 300°	307	307	307	605	1225	2450
F 0.5 θ = 1°	**2.56**	**2.56**	**2.56**	**5.04**	**10.2**	**20.4**
F 0.5θ = 300°	**766**	**766**	**766**	**1510**	**3060**	**6140**
F1 θ = 1°	5.11	5.11	5.11	10.1	20.4	40.9
F1 θ = 300°	1533	1533	1533	3022	6125	12,300
F2 θ = 1°	**10.22**	**10.22**	**10.22**	**20.1**	**40.8**	**81.8**
F2 θ = 300°	**3066**	**3066**	**3066**	**6044**	**12,250**	**24,500**
F3 θ = 1°	15.3	15.3	15.3	30.2	61.3	123
F3 θ = 300°	4600	4600	4600	9067	18,400	36,800
F4 θ = 1°	**20.4**	**20.4**	**20.4**	**40.3**	**81.7**	**164**
F4 θ = 300°	**6132**	**6132**	**6132**	**12,090**	**24,500**	**49,100**
F5 θ = 1°	25.6	25.6	25.6	50.4	102	205
F5 θ = 300°	7665	7665	7665	15,100	30,600	61,400
F10 θ = 1°	**51.1**	**51.1**	**51.1**	**100.7**	**204**	**409**
F10 θ = 300°	**15330**	**15330**	**15330**	**30,200**	**61,200**	**123,000**
SHEAR RATE RANGE						
Shear Rate Constant k_3, sec^{-1} per rpm	1.7023	5.4225	0.377	0.377	0.268	0.268
Shear Rate range, sec^{-1} $\Upsilon = k_3N$						
N = 0.9 rpm	1.5	4.9	0.4	0.4	0.24	0.24
N = 1.8 rpm	3.1	9.8	0.7	0.7	0.48	0.48
N = 3 rpm	**5.1**	**16.3**	**1.1**	**1.1**	**0.80**	**0.80**
N = 6 rpm	**10.2**	**32.5**	**2.3**	**2.3**	**1.61**	**1.61**
N = 30 rpm	51.1	163	11.3	11.3	8.0	8.0
N = 60 rpm	102	325	22.6	22.6	16.1	16.1
N = 90 rpm	**153**	**488**	**33.9**	**33.9**	**24.1**	**24.1**
N = 100 rpm	**170**	**542**	**37.7**	**37.7**	**26.8**	**26.8**
N = 180 rpm	306	976	67.9	67.9	48.2	48.2
N = 200 rpm	340	1084	75.4	75.4	53.6	53.6
N = 300 rpm	**511**	**1627**	**113**	**113**	**80.4**	**80.4**
N = 600 rpm	**1021**	**3254**	**226**	**226**	**161**	**161**
VISCOSITY RANGE IN CENTIPOISE(1)						
Minimum Viscosity(2) 600 rpm maximum	0.5(3)	0.5(3)	2.3	4.5	12.7	25
Maximum Viscosity(4)						
Model 35A & 35SA, 3 rpm minimum	30,000	9,400	135,000	270,000	762,000	1,500,000
Model 35A/SR 12 & 35SA/SR 12, 0.9 rpm min.	100,000	31,400	400,000	890,000	2,550,000	5,000,000

Notes:
(1) Computed for standard Torsion Spring (f = 1.) For other torsion springs multiply viscosity range by f factor.
(2) Minimum viscosity is computed for minimum shear stress and maximum shear rate.
(3) For practical purposes the minimum viscosity is limited to 0.5 cP because of Taylor Vortices.
(4) Maximum viscosity is computed for maximum shear stress and minimum shear rate.

Model 35 Viscometer
Torsion Spring Constants

Torsion Spring Assembly	Part Number	Torsion Spring Constant k1 (dyne-cm/deg. defl)	F Factor	Maximum Shear Stress With B1 Bob (dynes/cm2)	Color Code
F0.2	207656	77.2	0.2	307	Green
F0.5	207657	193	0.5	766	Yellow
F1	207465	386	1	1,533	Blue
F2	207658	772	2	3,066	Red
F3	207659	1,158	3	4,600	Purple
F4	207660	1,544	4	6,132	White
F5	207661	1,930	5	7,665	Black
F10	207662	3,860	10	15,330	Orange

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3. CSC Precision and Interfacial DuNouy Tensiometers

A	Knurled Knob	J	Wire Retaining Screw
B	Sample Table Adjustment Screw	K	Rear Clamp Spring Support
C	Dial Clamp	L	Base Leveling Screw
D	Adjustable Stops	M	Torsion Arm
F	Fine Adjustment Screw	R	Cap
G	Adjustment Nut	S	Dial
H	Hook	T	Sample Table
I	Index	V	Vernier
		Y	Torsion Wire Cover

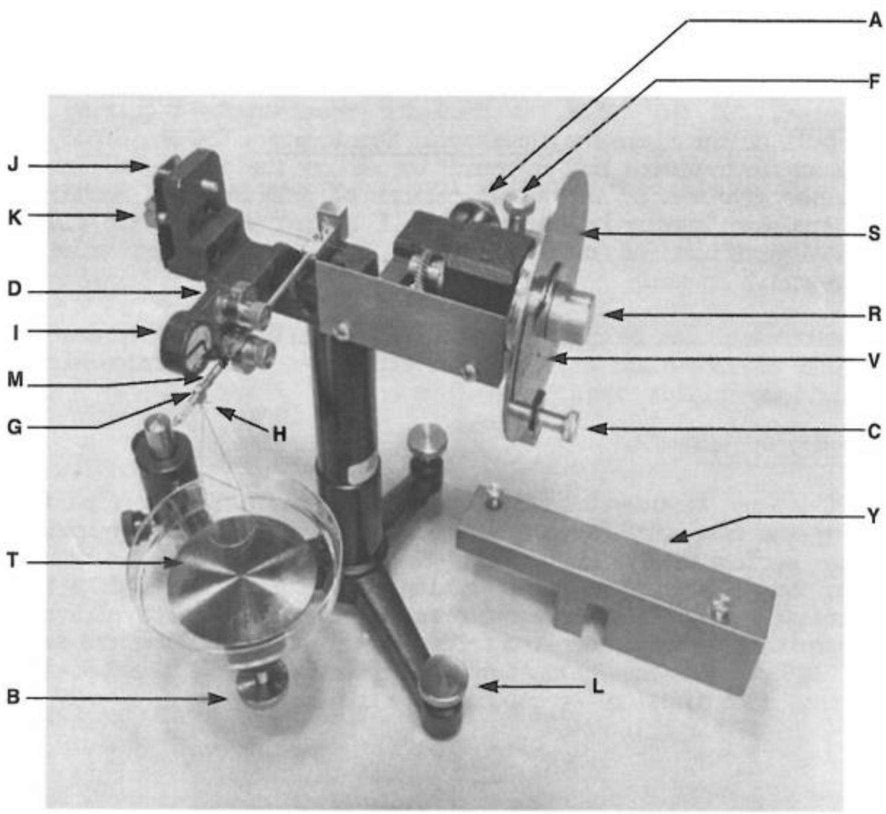

FIG. 1 - TENSIOMETER NO. 70535

A	Knurled Knob	L	Base Leveling Screw
B	Sample Table Adjustment Screw	M	Torsion Arm
C	Dial Clamp	N	Knurled Release
D	Adjustable Stops	P	Vertical Arm
E	Counter Weight	R	Cap
F	Fine Adjustment Screw	S	Dial
G	Adjustment Nuts	T	Sample Table
I	Index	V	Vernier
J	Wire Retaining Screw	X	Clamping Jaws
K	Rear Clamp Spring Support	Y	Torsion Wire Cover

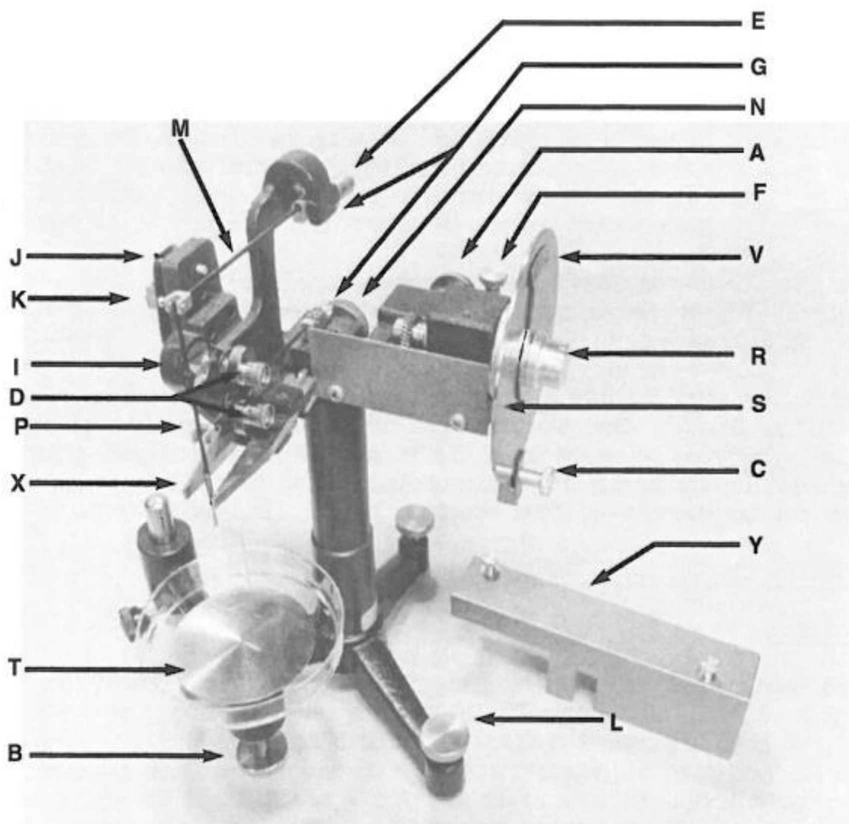

FIG. 2 - TENSIOMETER NO. 70545

The measuring procedure is as follows: Pour the liquid of greater density in the vessel to a depth of 10 mm or more, then pour water to a depth of 5mm on the surface of the denser liquid. Raise the vessel until the ring is immersed in the water and is in the interface of the liquids with the lever arm index at zero. Increase the torsion on the wire to force the ring downward and, simultaneously raise the vessel, keeping the lever arm index at zero. The scale reading when the film breaks is the apparent interfacial tension.

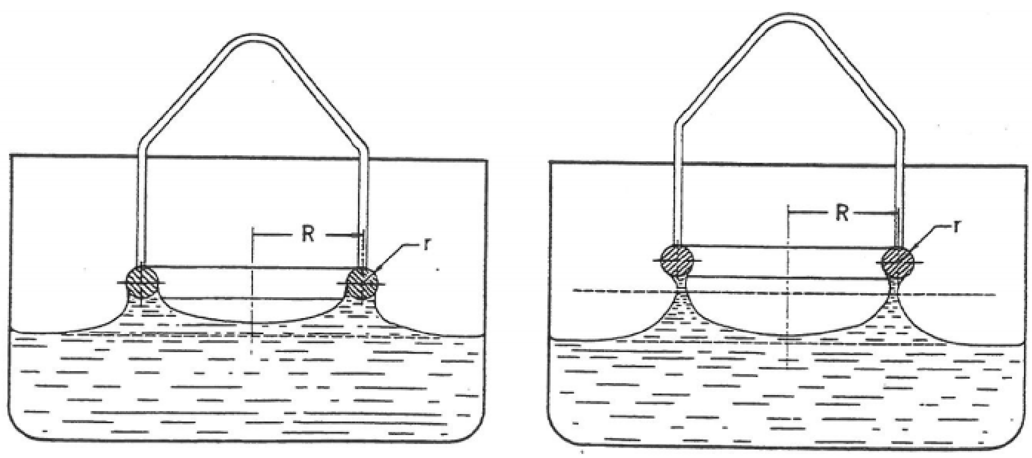

FIG. 3 - DISTENTION OF SURFACE FILM DURING SURFACE TENSION MEASUREMENT

FIG. 4 - CONDITION OF SURFACE FILM AT BREAKING POINT

This tensiometers operate with a precision of ± 0.05 dynes/cm.

Appendix C

Experimental Data

1. Polymer-surfactant Studies

1.1 Pure CMC solutions

concentration	100	300	500	700	1000	1500	2000
surface tension	68.3	67.8	67.8	67.9	68.2	68.1	68.1
	68.6	67.8	67.8	68	68.3	67.8	67.8
Avg.	68.45	67.8	67.8	67.95	68.25	67.95	67.95
Conductivity	0.137	0.395	0.627	0.654	1.216	1.732	2.324
	0.142	0.391	0.624	0.657	1.223	1.732	2.317
Avg.	0.1395	0.393	0.6255	0.6555	1.2195	1.732	2.3205

Comcentration	RPM	0.9	1.8	3	6	30	60	90	100
100ppm	Dail Reading	4.2	5.2	5.8	6.3	7.5	9.1	10.9	12.3
	Shear stress	0.00062	0.08872	0.14158	0.18563	0.29135	0.43231	0.59089	0.71423
	LN(shear stress)	-7.3857911	-2.4222699	-1.9548904	-1.684	-1.23323	-0.83861	-0.5261254	-0.3365502
	shear rate	1.62124265	3.2424853	5.40414217	10.808284	54.041422	108.0828	162.124265	180.138072
	Vicosity	0.00038242	0.02736173	0.02619842	0.0171748	0.0053912	0.004	0.00364467	0.0039649
	Relative viscosity	0.3824227	27.3617277	26.1984225	17.174789	5.3912349	3.999802	3.64467342	3.96490309
300ppm	Dail Reading	4.9	5.8	6	6.3	10.4	14.3	18.2	19.8
	Shear stress	0.06229	0.14158	0.1592	0.18563	0.54684	0.89043	1.23402	1.37498
	LN(shear stress)	-2.7759544	-1.9548904	-1.837594	-1.684	-0.603599	-0.11605	0.21027713	0.31843919
	Shear rate	1.57145124	3.14290248	5.23817081	10.476342	52.381708	104.7634	157.145124	174.605694
	viscosity	0.03963852	0.04504753	0.03039229	0.017719	0.0104395	0.008499	0.00785274	0.00787477
	Relative viscosity	39.6385191	45.0475319	30.3922888	17.718972	10.439522	8.499436	7.85274126	7.87477185
500ppm	Dail Reading	5	5.6	6.2	7.1	15	20.2	22	29
	Shear stress	0.0711	0.12396	0.17682	0.25611	0.9521	1.41022	1.5688	2.1855
	LN(shear stress)	-2.6436679	-2.0877963	-1.732623	-1.362148	-0.049085	0.343746	0.450311	0.78184464
	Shear rate	1.56826381	3.13652763	5.22754604	10.455092	52.27546	104.5509	156.826381	174.251535
	Vicosity	0.04533676	0.03952141	0.03382467	0.0244962	0.0182131	0.013488	0.01000342	0.01254221
	Relative viscosity	45.3367599	39.5214118	33.8246662	24.496197	18.213135	13.48836	10.003419	12.5422138
700ppm	Dail Reading	5.1	6	6.3	7	15.2	20.9	25	30.1
	Shear stress	0.07991	0.1592	0.18563	0.2473	0.96972	1.47189	1.8331	2.28241
	LN(shear stress)	-2.5268543	-1.837594	-1.6839998	-1.397153	-0.030748	0.386547	0.60600852	0.8252319
	Shear rate	1.56630747	3.13261493	5.22102489	10.44205	52.210249	104.4205	156.630747	174.034163
	Vicosity	0.05101808	0.05082016	0.03555432	0.0236831	0.0185734	0.014096	0.01170332	0.01311472
	Relative viscosity	51.0180802	50.8201625	35.554322	23.68309	18.573365	14.0958	11.7033216	13.1147239
1000ppm	Dail Reading	7.2	8	6.7	8.3	19.9	30	39.2	41.2
	Shear stress	0.26492	0.3354	0.22087	0.36183	1.38379	2.2736	3.08412	3.26032
	LN(shear stress)	-1.3283274	-1.0924314	-1.510181	-1.016581	0.3248261	0.821364	1.12626637	1.18182535
	Shear rate	1.56080624	3.12161248	5.20268747	10.405375	52.026875	104.0537	156.080624	173.422916
	Vicosity	0.16973279	0.10744447	0.04245306	0.0347734	0.0265976	0.02185	0.01975979	0.01879982
	Relative viscosity	169.732791	107.44447	42.4530594	34.773375	26.5976	21.85025	19.7597877	18.7998223

1500ppm	Dail Reading	5.5	7.1	11.3	13.9	30	45.2	56.3	60.5
	Shear stress	0.11515	0.25611	0.62613	0.85519	2.2736	3.61272	4.59063	4.96065
	LN(shear stress)	-2.1615197	-1.3621482	-0.4681973	-0.156432	0.8213645	1.284461	1.52401727	1.60153678
	Shear rate	1.59513177	3.19026353	5.31710589	10.634212	53.171059	106.3421	159.513177	177.236863
	Vicosity	0.07218839	0.08027863	0.11775767	0.0804187	0.0427601	0.033973	0.028779	0.02798882
	Relative viscosity	72.1883938	80.2786345	117.75767	80.418748	42.760104	33.97262	28.7790018	27.9888163
2000ppm	Dail Reading	8.8	9.3	9.9	13.6	36	55.4	74.7	78.1
	Shear stress	0.40588	0.44993	0.50279	0.82876	2.8022	4.51134	6.21167	6.51121
	LN(shear stress)	-0.9016977	-0.7986633	-0.6875827	-0.187825	1.0304048	1.506594	1.82642978	1.87352531
	Shear rate	1.56803416	3.13606832	5.22678053	10.453561	52.267805	104.5356	156.803416	174.226018
	Vicosity	0.2588464	0.14346945	0.09619497	0.0792802	0.0536124	0.043156	0.03961438	0.0373722
	Relative viscosity	258.846402	143.469451	96.1949706	79.280161	53.612352	43.15601	39.6143793	37.3722024

Flow Data

500ppm CMC in 1inch pipe											
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Blasius	FR in Vol
1.027	1	2	1.008	0.048218	0.126908	144.482	0.021077	0.8787167	0.1093167	0.0227863	4.8363E-05
1.045	1	2	1.033	0.07583	0.199581	263.026	0.024129	1.0059791	0.0506015	0.0196168	7.6058E-05
1.089	1	2	1.079	0.143326	0.377227	610.719	0.029746	1.2401418	0.0174613	0.0158916	0.00014376
1.123	1	2	1.165	0.195482	0.514499	920.842	0.040247	1.6779242	0.0127003	0.014341	0.00019607
1.178	1	2	1.298	0.279852	0.736557	1480.36	0.056486	2.3549599	0.0086973	0.0127361	0.00028069
1.246	1	2	1.549	0.384164	1.011102	2251.26	0.087133	3.6326738	0.0071195	0.0114689	0.00038532
1.317	1	2	1.837	0.493078	1.297758	3132.26	0.122298	5.0987359	0.0060658	0.01056	0.00049456
1.43	1	2	2.42	0.66642	1.753986	4666.33	0.193482	8.0664936	0.0052535	0.0095584	0.00066843
1.505	1	2	2.876	0.78147	2.056792	5760.95	0.24916	10.387759	0.0049199	0.0090678	0.00078382
1.591	1	2	3.422	0.913394	2.40401	7081.66	0.315826	13.167168	0.0045649	0.0086118	0.00091614
1.661	1	2	3.93	1.020774	2.686629	8203.67	0.377853	15.753139	0.0043728	0.0083009	0.00102385
1.755	1	2	4.639	1.16497	3.066146	9771.03	0.464422	19.362299	0.0041265	0.0079459	0.00116848
1.82	1	3	1.419	1.26468	3.328578	10892.6	0.502944	20.968327	0.0037919	0.0077329	0.00126849
1.927	1	3	1.51	1.428818	3.760582	12801.4	0.617431	25.741429	0.003647	0.007427	0.00143312
2.006	1	3	1.58	1.550004	4.079538	14257.4	0.705498	29.413047	0.003541	0.0072296	0.00155467
2.063	1	3	1.64	1.637442	4.309671	15331.2	0.780984	32.560148	0.0035125	0.0070996	0.00164237
2.119	1	3	1.697	1.723346	4.535766	16404.4	0.852696	35.549893	0.0034622	0.0069805	0.00172853
2.215	1	3	1.805	1.87061	4.923358	18284.4	0.988571	41.214674	0.0034068	0.0067937	0.00187624
2.335	1	3	1.935	2.05469	5.407848	20702.3	1.152124	48.033393	0.0032908	0.006586	0.00206087
2.43	1	3	2.048	2.20042	5.791402	22667.1	1.294289	53.960432	0.0032234	0.0064384	0.00220704
2.505	1	3	2.152	2.31547	6.094208	24248.4	1.425131	59.415407	0.0032054	0.0063308	0.00232244
2.573	1	3	2.232	2.419782	6.368753	25704.3	1.525779	63.611541	0.0031422	0.0062392	0.00242706
2.675	1	3	2.366	2.57625	6.780569	27926.2	1.694365	70.640066	0.0030784	0.0061112	0.002584
2.803	1	3	2.546	2.772602	7.297358	30776.6	1.920823	80.081368	0.0030131	0.0059645	0.00278094
3.042	1	3	2.895	3.139228	8.262301	36273.4	2.3599	98.387004	0.0028877	0.0057244	0.00314867
3.294	1	3	3.303	3.525796	9.27973	42298.3	2.873204	119.78729	0.0027871	0.0055087	0.00353641
3.422	1	3	3.521	3.722148	9.796519	45443	3.14747	131.22175	0.0027395	0.0054108	0.00373335
3.528	1	3	3.717	3.884752	10.22449	48088.1	3.394058	141.50228	0.002712	0.0053348	0.00389644
3.622	1	3	3.893	4.028948	10.604	50464	3.615483	150.73378	0.0026859	0.0052709	0.00404107
3.727	1	3	3.981	4.190018	11.02793	53150.6	3.726196	155.34953	0.0025594	0.005203	0.00420263
3.816	1	3	4.294	4.326544	11.38726	55454.2	4.119981	171.7669	0.0026541	0.0051481	0.00433956
3.91	1	3	4.478	4.47074	11.76678	57912.8	4.351472	181.41801	0.0026253	0.0050925	0.00448419

500ppm CMC in 1.5inch pipe											
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Blasius	FR in vol
1.036	2	2	1.006	0.062024	0.065419	98.38863	0.020833	0.409984	0.192114	0.025084	6.22E-05
1.089	2	2	1.024	0.143326	0.151172	289.6022	0.02303	0.453237	0.039773	0.01915	0.000144
1.094	2	2	1.033	0.150996	0.159262	309.7299	0.024129	0.474863	0.037545	0.018831	0.000151
1.138	2	2	1.082	0.218492	0.230453	498.6698	0.030112	0.592606	0.022377	0.016718	0.000219
1.201	2	2	1.162	0.315134	0.332385	799.5123	0.03988	0.784839	0.014246	0.014857	0.000316
1.255	2	2	1.246	0.39797	0.419755	1080.094	0.050137	0.986685	0.01123	0.01378	0.000399
1.318	2	2	1.387	0.494612	0.521688	1429.395	0.067353	1.325496	0.009767	0.012848	0.000496
1.382	2	2	1.51	0.592788	0.625238	1805.114	0.082371	1.621055	0.008316	0.01212	0.000595
1.451	2	2	1.664	0.698634	0.736878	2230.838	0.101174	1.991105	0.007354	0.011495	0.000701
1.564	2	2	1.961	0.871976	0.919709	2968.458	0.137438	2.704772	0.006413	0.010703	0.000875
1.65	2	2	2.213	1.0039	1.058855	3559.536	0.168207	3.310307	0.005921	0.010228	0.001007
1.757	2	2	2.563	1.168038	1.231978	4326.731	0.210942	4.151329	0.005485	0.009741	0.001172
1.843	2	2	2.845	1.299962	1.371124	4966.608	0.245375	4.828952	0.005151	0.00941	0.001304
1.939	2	2	3.203	1.447226	1.526449	5703.349	0.289086	5.689197	0.004897	0.009091	0.001452
2.088	2	2	3.773	1.675792	1.767527	6889.884	0.358683	7.058861	0.004531	0.008671	0.001681
2.207	2	2	4.238	1.858338	1.960066	7872.079	0.41546	8.176218	0.004268	0.008387	0.001864
2.336	2	2	4.85	2.056224	2.168785	8968.733	0.490185	9.646804	0.004113	0.008118	0.002062
2.493	2	3	1.451	2.297062	2.422807	10344.99	0.543203	10.6902	0.003652	0.007833	0.002304
2.544	2	3	1.48	2.375296	2.505323	10801.33	0.579688	11.40822	0.003645	0.007749	0.002382
2.59	2	3	1.502	2.44586	2.57975	11216.67	0.607366	11.95292	0.003602	0.007676	0.002453
2.713	2	3	1.556	2.634542	2.778761	12344.16	0.675304	13.28992	0.003452	0.007495	0.002642
2.856	2	3	1.634	2.853904	3.010131	13684.55	0.773435	15.22115	0.003369	0.007304	0.002862
3.119	2	3	1.786	3.257346	3.435658	16227.25	0.964667	18.98457	0.003225	0.006999	0.003267
3.228	2	3	1.841	3.424552	3.612017	17308.74	1.033862	20.34633	0.003127	0.006887	0.003435
3.413	2	3	1.956	3.708342	3.911342	19179.2	1.178544	23.19365	0.00304	0.006713	0.00372
3.609	2	3	2.082	4.009006	4.228465	21206.48	1.337064	26.31332	0.002951	0.006547	0.004021
3.965	2	3	2.314	4.55511	4.804464	25000.79	1.628943	32.05748	0.002785	0.006283	0.004569
4.211	2	3	2.482	4.932474	5.202485	27701.66	1.840304	36.21705	0.002683	0.006124	0.004947
4.583	2	3	2.763	5.503122	5.804371	31899.64	2.19383	43.17442	0.00257	0.005911	0.00552
4.731	2	3	2.872	5.730154	6.043831	33605.87	2.330963	45.87318	0.002518	0.005835	0.005747
4.945	2	3	3.034	6.05843	6.390078	36107.59	2.534775	49.88419	0.00245	0.005731	0.006077
5.129	2	3	3.207	6.340686	6.687785	38290.23	2.752427	54.16755	0.002429	0.005647	0.00636

700ppm CMC in 1inch pipe											
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Blasius	FR in Vol
1.088	1	2	1.366	0.141792	0.3701492	586.2848	0.0647886	2.7011134	0.0391786	0.0160546	0.000142219
1.105	1	2	1.426	0.16787	0.438226	732.0626	0.0721146	3.006543	0.0311122	0.0151876	0.000168375
1.151	1	2	1.534	0.238434	0.6224339	1161.4312	0.0853014	3.5563164	0.018242	0.0135325	0.000239151
1.23	1	2	1.801	0.35962	0.938791	1994.0797	0.1179021	4.9154781	0.0110838	0.011822	0.000360702
1.338	1	2	2.259	0.525292	1.3712791	3282.3453	0.1738239	7.2469242	0.0076588	0.0104371	0.000526873
1.495	1	2	3.016	0.76613	1.9999888	5392.1772	0.2662536	11.100428	0.005515	0.009219	0.000768435
1.532	1	2	3.219	0.822888	2.148156	5923.6416	0.2910399	12.133798	0.0052255	0.0090049	0.000825364
1.601	1	2	3.504	0.928734	2.4244679	6945.5814	0.3258384	13.584589	0.0045928	0.0086537	0.000931529
1.723	1	2	4.36	1.115882	2.9130193	8842.4666	0.430356	17.942051	0.0042019	0.0081467	0.00111924
1.787	1	2	4.879	1.214058	3.1693085	9879.6429	0.4937259	20.584017	0.0040725	0.007924	0.001217711
1.855	1	3	1.459	1.31837	3.4416159	11010.986	0.5532679	23.066394	0.00387	0.0077121	0.001322337
1.949	1	3	1.536	1.462566	3.8180407	12621.69	0.6501416	27.105173	0.0036951	0.0074533	0.001466967
2.005	1	3	1.572	1.54847	4.0422939	13605.68	0.6954332	28.993433	0.0035262	0.0073147	0.001553129
2.061	1	3	1.627	1.634374	4.266547	14607.042	0.7646287	31.878276	0.0034802	0.007186	0.001639292
2.111	1	3	1.678	1.711074	4.466773	15515.278	0.8287918	34.553311	0.0034416	0.0070784	0.001716223
2.211	1	3	1.714	1.864474	4.8672249	17370.162	0.8740834	36.441572	0.003057	0.0068814	0.001870084
2.317	1	3	1.895	2.027078	5.291704	19389.555	1.1017995	45.935326	0.00326	0.0066948	0.002033178
2.439	1	3	2.033	2.214226	5.7802555	21777.676	1.2754173	53.173657	0.0031627	0.0065032	0.002220889
2.59	1	3	2.215	2.44586	6.3849379	24822.481	1.5043915	62.719863	0.0030574	0.0062938	0.00245322
2.683	1	3	2.324	2.588522	6.7573583	26744.115	1.6415244	68.437096	0.0029785	0.0061776	0.002596311
2.845	1	3	2.552	2.83703	7.4060905	30171.232	1.9283712	80.396078	0.0029128	0.0059942	0.002845567
3.168	1	3	3.029	3.332512	8.6995504	37285.74	2.5284849	105.41553	0.002768	0.0056851	0.00334254
3.403	1	3	3.399	3.693002	9.6406125	42679.117	2.9939819	124.82265	0.002669	0.0054963	0.003704114
3.558	1	3	3.669	3.930772	10.261313	46329.524	3.3336689	138.9846	0.0026231	0.0053847	0.0039426
3.699	1	3	3.92	4.147066	10.82595	49711.376	3.649452	152.14997	0.0025799	0.0052907	0.004159545
3.815	1	3	4.12	4.32501	11.290475	52535.754	3.901072	162.64031	0.0025355	0.0052181	0.004338024
3.947	1	3	4.395	4.527498	11.819071	55794.514	4.2470495	177.06452	0.002519	0.0051402	0.004541121

700ppm CMC in 1.5inch pipe

FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Blasius	FR in Vol
1.059	2	2	1.025	0.097306	0.1017047	145.45118	0.0231525	0.4556395	0.0875385	0.0227482	9.75988E-05
1.102	2	2	1.063	0.163268	0.1706484	287.30686	0.0277923	0.5469504	0.0373252	0.0191885	0.000163759
1.21	2	2	1.184	0.32894	0.3438095	721.90624	0.0425664	0.8377036	0.0140836	0.0152408	0.00032993
1.309	2	2	1.371	0.480806	0.5025405	1189.3569	0.0653991	1.2870494	0.0101277	0.0134524	0.000482253
1.416	2	2	1.595	0.644944	0.6740983	1750.1751	0.0927495	1.8253032	0.0079827	0.012214	0.000646885
1.53	2	2	1.903	0.81982	0.8568795	2399.5576	0.1303563	2.5654022	0.0069435	0.0112874	0.000822287
1.634	2	2	2.202	0.979356	1.0236272	3031.8057	0.1668642	3.283875	0.0062282	0.0106464	0.000982303
1.691	2	2	2.69	1.066794	1.1150178	3392.7478	0.226449	4.4564994	0.0071234	0.0103512	0.001070004
1.841	2	2	2.86	1.296894	1.3555193	4386.5237	0.247206	4.8649956	0.0052618	0.0097073	0.001300796
1.895	2	2	3.107	1.37973	1.4420999	4758.7009	0.2773647	5.4585165	0.0052161	0.0095116	0.001383882
1.954	2	2	3.303	1.470236	1.5366971	5173.4637	0.3012963	5.9294886	0.00499	0.009315	0.00147466
2.01	2	2	3.554	1.55614	1.6264844	5574.6657	0.3319434	6.5326213	0.0049074	0.0091427	0.001560822
2.158	2	2	4.187	1.783172	1.8637792	6668.247	0.4092327	8.0536689	0.0046075	0.0087423	0.001788538
2.247	2	2	4.507	1.919698	2.0064768	7347.7347	0.4483047	8.822603	0.004355	0.0085327	0.001925474
2.282	2	2	4.72	1.973388	2.0625938	7619.2144	0.474312	9.3344247	0.0043603	0.0084557	0.001979326
2.347	2	3	1.404	2.073098	2.1668111	8129.5645	0.4840724	9.5265086	0.0040323	0.0083197	0.002079336
2.389	2	3	1.419	2.137526	2.2341516	8463.4939	0.5029439	9.8978983	0.0039407	0.0082364	0.002143958
2.443	2	3	1.446	2.220362	2.3207321	8897.5087	0.5369126	10.5664	0.0038988	0.0081341	0.002227043
2.525	2	3	1.488	2.34615	2.4522063	9566.3478	0.5897528	11.606291	0.0038356	0.007988	0.00235321
2.584	2	3	1.514	2.436656	2.5468036	10054.666	0.6224634	12.250033	0.0037532	0.0078892	0.002443988
2.694	2	3	1.566	2.605396	2.7231714	10980.344	0.6878846	13.537517	0.0036278	0.0077174	0.002613236
2.837	2	3	1.647	2.824758	2.9524495	12212.17	0.7897907	15.543022	0.0035435	0.007515	0.002833258
2.912	2	3	1.683	2.939808	3.0727002	12870.551	0.8350823	16.434357	0.0034592	0.007417	0.002948654
3.021	2	3	1.754	3.107014	3.2474647	13841.917	0.9244074	18.192268	0.0034281	0.0072833	0.003116363
3.166	2	3	1.833	3.329444	3.4799495	15159.774	1.0237973	20.148254	0.0033064	0.0071196	0.003339462
3.404	2	3	1.98	3.694536	3.8615453	17383.161	1.208738	23.787873	0.0031702	0.0068801	0.003705653
3.551	2	3	2.076	3.920034	4.0972368	18791.928	1.3295156	26.164768	0.0030974	0.0067474	0.003931829
3.777	2	3	2.224	4.266718	4.4595924	21007.761	1.5157144	29.829146	0.0029806	0.0065619	0.004279557
3.992	2	3	2.383	4.596528	4.8043113	23169.213	1.7157523	33.765877	0.0029072	0.0064032	0.004610359
4.297	2	3	2.601	5.064398	5.293331	26319.805	1.9900181	39.163407	0.0027777	0.0062024	0.005079637
4.616	2	3	2.851	5.553744	5.8047976	29714.676	2.3045431	45.353236	0.0026748	0.0060171	0.005570455
4.786	2	3	3.005	5.814524	6.077366	31563.322	2.4982905	49.16617	0.0026454	0.005927	0.00583202
4.908	2	3	3.089	6.001672	6.272974	32906.274	2.6039709	51.245953	0.002588	0.0058655	0.006019731
5.1	2	3	3.252	6.2962	6.5808159	35046.543	2.8090412	55.281721	0.0025368	0.0057739	0.006315145
5.122	2	3	3.367	6.329948	6.6160895	35293.833	2.9537227	58.129042	0.0026391	0.0057637	0.006348995

1000ppm CMC in 1inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in Vol
1.207	1	2	1.514	0.324338	0.852873	1102.978	0.082859	3.454506	0.009507	0.000325
1.335	1	2	2.043	0.52069	1.369197	2034.442	0.14745	6.147378	0.006564	0.000522
1.394	1	2	2.313	0.611196	1.60719	2502.999	0.180417	7.521811	0.005829	0.000613
1.458	1	2	2.633	0.709372	1.865352	3034.791	0.219489	9.150769	0.005264	0.000712
1.584	1	2	3.302	0.902656	2.373608	4144.483	0.301174	12.55631	0.004461	0.000905
1.63	1	2	3.577	0.97322	2.559162	4568.217	0.334752	13.95619	0.004266	0.000976
1.757	1	2	4.338	1.168038	3.071452	5784.096	0.42767	17.83006	0.003783	0.001172
1.823	1	2	4.866	1.269282	3.337681	6440.582	0.492139	20.51784	0.003687	0.001273
1.929	1	3	1.455	1.431886	3.765262	7527.136	0.548236	22.85659	0.003227	0.001436
2.126	1	3	1.606	1.734084	4.559916	9642.348	0.738209	30.77679	0.002963	0.001739
2.278	1	3	1.726	1.967252	5.173051	11351.22	0.889181	37.07099	0.002773	0.001973
2.605	1	3	2.02	2.46887	6.492097	15226.89	1.259062	52.49179	0.002493	0.002476
2.86	1	3	2.281	2.86004	7.52071	18417.02	1.587426	66.18167	0.002342	0.002869
3.114	1	3	2.556	3.249676	8.54529	21724.82	1.933404	80.60588	0.00221	0.003259
3.388	1	3	2.88	3.669992	9.650546	25425.81	2.341028	97.60023	0.002098	0.003681
3.65	1	3	3.226	4.0719	10.7074	29083.32	2.776331	115.7485	0.002021	0.004084
3.858	1	3	3.504	4.390972	11.54642	32063.96	3.126082	130.3301	0.001957	0.004404

1000ppm CMC in 1.5inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in Vol
1.085	2	2	1.051	0.13719	0.144439	153.3345	0.026327	0.518115	0.049714	0.000138
1.108	2	2	1.105	0.172472	0.181586	206.1527	0.032921	0.647873	0.039332	0.000173
1.307	2	2	1.401	0.477738	0.502982	769.9047	0.069062	1.359137	0.010754	0.000479
1.403	2	2	1.667	0.625002	0.658028	1089.819	0.101541	1.998313	0.009238	0.000627
1.589	2	2	2.177	0.910326	0.958429	1772.435	0.163812	3.223802	0.007025	0.000913
1.723	2	2	2.593	1.115882	1.174847	2306.352	0.214605	4.223416	0.006125	0.001119
1.839	2	2	3.006	1.293826	1.362193	2792.736	0.265033	5.215822	0.005627	0.001298
1.929	2	2	3.351	1.431886	1.507549	3184.031	0.307157	6.044829	0.005324	0.001436
2.115	2	2	4.065	1.71721	1.80795	4027.522	0.394337	7.760513	0.004753	0.001722
2.258	2	2	4.63	1.936572	2.038903	4705.02	0.463323	9.118162	0.004391	0.001942
2.477	2	3	1.451	2.272518	2.392601	5786.444	0.543203	10.6902	0.003738	0.002279
2.994	2	3	1.69	3.065596	3.227586	8522.178	0.843889	16.60767	0.003191	0.003075
3.245	2	3	1.815	3.45063	3.632966	9931.271	1.001152	19.70259	0.002988	0.003461
3.478	2	3	1.924	3.808052	4.009274	11281.42	1.138284	22.40135	0.00279	0.00382
3.887	2	3	2.165	4.435458	4.669833	13741.25	1.441487	28.36835	0.002604	0.004449
4.263	2	3	2.38	5.012242	5.277095	16095.05	1.711978	33.6916	0.002422	0.005027
4.624	2	3	2.597	5.566016	5.860131	18431.19	1.984986	39.06437	0.002277	0.005583

1.2 CMC-Alfonic 1412-9 Ethoxylate

Surface tension	250ppm CMC + Alfonic 1412-9										
concentration(ppm)	0	1	2	5	7	10	20	50	70	100	150
	69.5	67	65.3	57.2	50.7	44	38.9	36.4	34.1	33.4	33
	68.6	66.2	64.9	55.3	50.4	43.2	39	35.2	33.6	33.3	33.1
Avg.	69.05	66.6	65.1	56.25	50.55	43.6	38.95	35.8	33.85	33.35	33.05
Surface Tension	500ppm CMC + Alfonic 1412-9										
Alfonic Concentrati	0	1	2	5	7	10	20	50	70	100	150
	68.2	59.7	58.4	55.2	48.5	42.2	38.6	35.7	32.5	32.8	33
	68.9	59.5	56.7	54	46.4	40.7	37.4	34	32.5	32.7	32.2
average	68.55	59.6	57.55	54.6	47.45	41.45	38	34.85	32.5	32.75	32.6
Surface tension	700ppm CMC +Alfonic 1412-9										
concentration(ppm)	1	2	5	7	10	20	50	70	100	150	
	61.5	59.2	55.5	49	46.7	40.3	36	34.4	33.9	34.1	
	62.3	58	52.6	48.7	45.2	38.9	35.7	33.6	34.1	32.6	
Avg.	61.9	58.6	54.05	48.85	45.95	39.6	35.85	34	34	33.35	
Surface tension	1000ppm CMC + Alfonic 1412-9										
Concentration	1	2	5	7	10	20	30	40	50	70	100
	66	58.3	53.7	50.7	46.4	43.6	38.2	35	33.5	33	33.4
	64	55.2	52	48.1	44.5	42.5	36.4	34.4	33.2	33.1	33.1
Avg.	65	56.75	52.85	49.4	45.45	43.05	37.3	34.7	33.35	33.05	33.25

Conductivity	250ppm CMC with alfonic										
concentration(ppm)	0	1	2	5	7	10	20	50	70	100	150
	0.294	0.302	0.293	0.293	0.288	0.292	0.308	0.305	0.289	0.292	0.287
	0.294	0.302	0.292	0.296	0.289	0.295	0.306	0.306	0.291	0.294	0.289
Avg.	0.294	0.302	0.2925	0.2945	0.2885	0.2935	0.307	0.3055	0.29	0.293	0.288
Conductivity	500ppm CMC with alfonic										
Alfonic Concentrati	0	1	2	5	7	10	20	50	70	100	150
	0.569	0.57	0.559	0.556	0.561	0.555	0.546	0.55	0.549	0.556	0.556
	0.562	0.568	0.567	0.557	0.559	0.558	0.547	0.547	0.548	0.558	0.554
average	0.5655	0.569	0.563	0.5565	0.56	0.5565	0.5465	0.5485	0.5485	0.557	0.555
Conductivity	700ppm CMC with alfonic										
concentration(ppm)	1	2	5	7	10	20	50	70	100	150	
	0.787	0.771	0.776	0.767	0.77	0.781	0.767	0.775	0.773	0.767	
	0.786	0.782	0.771	0.772	0.771	0.783	0.764	0.775	0.771	0.768	
Avg.	0.7865	0.7765	0.7735	0.7695	0.7705	0.782	0.7655	0.775	0.772	0.7675	
Conductivity	1000ppm CMC with alfonic										
Concentration	1	2	5	7	10	20	30	40	50	70	100
	1.085	1.102	1.08	1.083	1.102	1.101	1.104	1.087	1.084	1.086	1.082
	1.085	1.099	1.081	1.082	1.103	1.097	1.103	1.099	1.101	1.09	1.086
Avg.	1.085	1.1005	1.0805	1.0825	1.1025	1.099	1.1035	1.093	1.0925	1.088	1.084

Viscosity	250ppm CMC +Alfonic										
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
0ppm	Dail Reading	4.1	4.3	5.7	6.9	9.2	12.9	16	17.4	24.8	25.9
	Shear stress	-0.00819	0.00943	0.13277	0.23849	0.44112	0.76709	1.0402	1.16354	1.81548	1.91239
	LN(shear stress)	/	-4.66386	-2.01914	-1.43343	-0.81844	-0.26515	0.039413	0.151467	0.59635	0.648354
	shear rate	1.52982	3.05964	5.099401	10.1988	50.99401	101.988	152.982	169.98	305.964	339.96
	Vicosity	-0.00535	0.003082	0.026036	0.023384	0.00865	0.007521	0.006799	0.006845	0.005934	0.005625
1ppm	Dail Reading	4.1	5.1	5.8	6.5	9.8	13.5	16.6	17.4	24.7	26.6
	Shear stress	-0.00819	0.07991	0.14158	0.20325	0.49398	0.81995	1.09306	1.16354	1.80667	1.97406
	LN(shear stress)	/	-2.52685	-1.95489	-1.59332	-0.70526	-0.19851	0.088981	0.151467	0.591485	0.680092
	shear rate	1.585027	3.170054	5.283423	10.56685	52.83423	105.6685	158.5027	176.1141	317.0054	352.2282
	Vicosity	-0.00517	0.025208	0.026797	0.019235	0.00935	0.00776	0.006896	0.006607	0.005699	0.005604
2ppm	Dail Reading	4.3	5	5.4	6.1	10.1	13.9	16.5	17.6	24.4	26.8
	Shear stress	0.00943	0.0711	0.10634	0.16801	0.52041	0.85519	1.08425	1.18116	1.78024	1.99168
	LN(shear stress)	-4.66386	-2.64367	-2.24111	-1.78373	-0.65314	-0.15643	0.080889	0.166497	0.576748	0.688979
	shear rate	1.544605	3.08921	5.148684	10.29737	51.48684	102.9737	154.4605	171.6228	308.921	343.2456
	Vicosity	0.006105	0.023016	0.020654	0.016316	0.010108	0.008305	0.00702	0.006882	0.005763	0.005802
5ppm	Dail Reading	4.5	5.5	5.2	6	10	13.5	16.1	17.2	24.2	26.1
	Shear stress	0.02705	0.11515	0.08872	0.1592	0.5116	0.81995	1.04901	1.14592	1.76262	1.93001
	LN(shear stress)	-3.61007	-2.16152	-2.42227	-1.83759	-0.67021	-0.19851	0.047847	0.136208	0.566801	0.657525
	shear rate	1.567665	3.13533	5.225549	10.4511	52.25549	104.511	156.7665	174.185	313.533	348.3699
	Vicosity	0.017255	0.036727	0.016978	0.015233	0.00979	0.007846	0.006692	0.006579	0.005622	0.00554
7ppm	Dail Reading	4.6	5.3	5.5	6.2	10	13.8	15.9	17.9	24.6	26.3
	Shear stress	0.03586	0.09753	0.11515	0.17682	0.5116	0.84638	1.03139	1.20759	1.79786	1.94763
	LN(shear stress)	-3.32813	-2.3276	-2.16152	-1.73262	-0.67021	-0.16679	0.030907	0.188627	0.586597	0.666613
	shear rate	1.575244	3.150487	5.250812	10.50162	52.50812	105.0162	157.5244	175.0271	315.0487	350.0541
	Vicosity	0.022765	0.030957	0.02193	0.016837	0.009743	0.00806	0.006547	0.006899	0.005707	0.005564
10ppm	Dail Reading	4.2	4.9	5.2	6	10	13.8	16.2	17.8	24.5	26
	Shear stress	0.00062	0.06229	0.08872	0.1592	0.5116	0.84638	1.05782	1.19878	1.78905	1.9212
	LN(shear stress)	-7.38579	-2.77595	-2.42227	-1.83759	-0.67021	-0.16679	0.05621	0.181304	0.581685	0.65295
	shear rate	1.568154	3.136308	5.22718	10.45436	52.2718	104.5436	156.8154	174.2393	313.6308	348.4787
	Vicosity	0.000395	0.019861	0.016973	0.015228	0.009787	0.008096	0.006746	0.00688	0.005704	0.005513
20ppm	Dail Reading	4.4	5.1	5.4	6.3	10.3	14	16.9	17.6	25.2	26.8
	Shear stress	0.01824	0.07991	0.10634	0.18563	0.53803	0.864	1.11949	1.18116	1.85072	1.99168
	LN(shear stress)	-4.00414	-2.52685	-2.24111	-1.684	-0.61984	-0.14618	0.112873	0.166497	0.615575	0.688979
	shear rate	1.557692	3.115385	5.192308	10.38462	51.92308	103.8462	155.7692	173.0769	311.5385	346.1539
	Vicosity	0.01171	0.02565	0.02048	0.017875	0.010362	0.00832	0.007187	0.006824	0.005941	0.005754
50ppm	Dail Reading	4.6	5.2	5.9	6.5	10.2	13.7	16.9	17.3	25.1	26.2
	Shear stress	0.03586	0.08872	0.15039	0.20325	0.52922	0.83757	1.11949	1.15473	1.84191	1.93882
	LN(shear stress)	-3.32813	-2.42227	-1.89452	-1.59332	-0.63635	-0.17725	0.112873	0.143867	0.610803	0.66208
	shear rate	1.575985	3.15197	5.253283	10.50657	52.53283	105.0657	157.5985	175.1094	315.197	350.2188
	Vicosity	0.022754	0.028147	0.028628	0.019345	0.010074	0.007972	0.007103	0.006594	0.005844	0.005536
70ppm	Dail Reading	4.8	5.2	5.6	6.2	10.2	13.9	17	17.8	24.8	26
	Shear stress	0.05348	0.08872	0.12396	0.17682	0.52922	0.85519	1.1283	1.19878	1.81548	1.9212
	LN(shear stress)	-2.92845	-2.42227	-2.0878	-1.73262	-0.63635	-0.15643	0.120712	0.181304	0.59635	0.65295
	shear rate	1.579764	3.159528	5.26588	10.53176	52.6588	105.3176	157.9764	175.5293	315.9528	351.0587
	Vicosity	0.033853	0.02808	0.02354	0.016789	0.01005	0.00812	0.007142	0.00683	0.005746	0.005473
100ppm	Dail Reading	4.2	4.9	5.1	5.8	9.7	13.6	16.7	17.2	24.2	26
	Shear stress	0.00062	0.06229	0.07991	0.14158	0.48517	0.82876	1.10187	1.14592	1.76262	1.9212
	LN(shear stress)	-7.38579	-2.77595	-2.52685	-1.95489	-0.72326	-0.18782	0.097009	0.136208	0.566801	0.65295
	shear rate	1.565759	3.131518	5.219196	10.43839	52.19196	104.3839	156.5759	173.9732	313.1518	347.9464
	Vicosity	0.000396	0.019891	0.015311	0.013563	0.009296	0.00794	0.007037	0.006587	0.005629	0.005522
150ppm	Dail Reading	4.9	5.3	5.7	6.5	10.7	13.8	16.8	17.3	24.9	26.6
	Shear stress	0.06229	0.09753	0.13277	0.20325	0.57327	0.84638	1.11068	1.15473	1.82429	1.97406
	LN(shear stress)	-2.77595	-2.3276	-2.01914	-1.59332	-0.5564	-0.16679	0.104972	0.143867	0.601191	0.680092
	shear rate	1.585741	3.171482	5.285803	10.57161	52.85803	105.7161	158.5741	176.1934	317.1482	352.3868
	Vicosity	0.039281	0.030752	0.025118	0.019226	0.010845	0.008006	0.007004	0.006554	0.005752	0.005602

Vsicosity	500ppmCMC +Alfonic										
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reading	4.2	4.7	5.2	6.2	12.5	18.3	23	24.2	34.9	
	Shear stress	0.00062	0.04467	0.08872	0.17682	0.73185	1.24283	1.6569	1.76262	2.70529	
	LN(shear stress)	-7.38579	-3.10845	-2.42227	-1.73262	-0.31218	0.217391	0.504948	0.566801	0.995209	
	shear rate	1.544595	3.08919	5.148651	10.2973	51.48651	102.973	154.4595	171.6217	308.919	
	Vicosity	0.000401	0.01446	0.017232	0.017171	0.014214	0.012069	0.010727	0.01027	0.008757	
2ppm	Dail Reading	5	5.2	5.7	6.5	12.7	19.8	24.7	26.1	37.1	39.4
	Shear stress	0.0711	0.08872	0.13277	0.20325	0.74947	1.37498	1.80667	1.93001	2.89911	3.10174
	LN(shear stress)	-2.64367	-2.42227	-2.01914	-1.59332	-0.28839	0.318439	0.591485	0.657525	1.064404	1.131963
	shear rate	1.566317	3.132635	5.221058	10.44212	52.21058	104.4212	156.6317	174.0353	313.2635	348.0705
	Vicosity	0.045393	0.028321	0.02543	0.019464	0.014355	0.013168	0.011535	0.01109	0.009255	0.008911
5ppm	Dail Reading	5	5.3	5.6	6.7	13.2	21.7	24.9	26.3	34.7	37.8
	Shear stress	0.0711	0.09753	0.12396	0.22087	0.79352	1.54237	1.82429	1.94763	2.68767	2.96078
	LN(shear stress)	-2.64367	-2.3276	-2.0878	-1.51018	-0.23128	0.43332	0.601191	0.666613	0.988675	1.085453
	shear rate	1.567186	3.134371	5.223952	10.4479	52.23952	104.479	156.7186	174.1317	313.4371	348.2635
	Vicosity	0.045368	0.031116	0.023729	0.02114	0.01519	0.014762	0.011641	0.011185	0.008575	0.008502
7ppm	Dail Reading	5.4	6.2	5.9	6.9	14	20.7	24	25.4	36	38.3
	Shear stress	0.10634	0.17682	0.15039	0.23849	0.864	1.45427	1.745	1.86834	2.8022	3.00483
	LN(shear stress)	-2.24111	-1.73262	-1.89452	-1.43343	-0.14618	0.374504	0.556755	0.62505	1.030405	1.100221
	shear rate	1.584524	3.169048	5.281747	10.56349	52.81747	105.6349	158.4524	176.0582	316.9048	352.1165
	Vicosity	0.067112	0.055796	0.028474	0.022577	0.016358	0.013767	0.011013	0.010612	0.008842	0.008534
10ppm	Dail Reading	4.4	5.3	5.7	7	13.1	19.9	25.4	26	35.9	38.4
	Shear stress	0.01824	0.09753	0.13277	0.2473	0.78471	1.38379	1.86834	1.9212	2.79339	3.01364
	LN(shear stress)	-4.00414	-2.3276	-2.01914	-1.39715	-0.24244	0.324826	0.62505	0.65295	1.027256	1.103149
	shear rate	1.548276	3.096552	5.160921	10.32184	51.60921	103.2184	154.8276	172.0307	309.6552	344.0614
	Vicosity	0.011781	0.031496	0.025726	0.023959	0.015205	0.013406	0.012067	0.011168	0.009021	0.008759
20ppm	Dail Reading	5.3	5.5	5.6	6.3	12.5	18.7	22.9	24.3	33.6	37.3
	Shear stress	0.09753	0.11515	0.12396	0.18563	0.73185	1.27807	1.64809	1.77143	2.59076	2.91673
	LN(shear stress)	-2.3276	-2.16152	-2.0878	-1.684	-0.31218	0.245351	0.499617	0.571787	0.951951	1.070463
	shear rate	1.575484	3.150968	5.251613	10.50323	52.51613	105.0323	157.5484	175.0538	315.0968	350.1075
	Vicosity	0.061905	0.036544	0.023604	0.017674	0.013936	0.012168	0.010461	0.010119	0.008222	0.008331
50ppm	Dail Reading	5.4	5.3	7	8.4	13.9	18.9	22.7	24.3	35.1	38
	Shear stress	0.10634	0.09753	0.2473	0.37064	0.85519	1.29569	1.63047	1.77143	2.72291	2.9784
	LN(shear stress)	-2.24111	-2.3276	-1.39715	-0.99252	-0.15643	0.259043	0.488868	0.571787	1.001701	1.091386
	shear rate	1.586998	3.173996	5.289994	10.57999	52.89994	105.7999	158.6998	176.3331	317.3996	352.6663
	Vicosity	0.067007	0.030728	0.046749	0.035032	0.016166	0.012247	0.010274	0.010046	0.008579	0.008445
70ppm	Dail Reading	5.6	6.7	7.1	7.3	13.7	18.6	24.2	25	35.9	38.1
	Shear stress	0.12396	0.22087	0.25611	0.27373	0.83757	1.26926	1.76262	1.8331	2.79339	2.98721
	LN(shear stress)	-2.0878	-1.51018	-1.36215	-1.29561	-0.17725	0.238434	0.566801	0.606009	1.027256	1.09434
	shear rate	1.600539	3.201077	5.335129	10.67026	53.35129	106.7026	160.0539	177.8376	320.1077	355.6752
	Vicosity	0.077449	0.068999	0.048004	0.025654	0.015699	0.011895	0.011013	0.010308	0.008726	0.008399
100ppm	Dail Reading	4.5	5.6	7.4	8.5	12.8	18.7	22.9	24	34.8	36.6
	Shear stress	0.02705	0.12396	0.28254	0.37945	0.75828	1.27807	1.64809	1.745	2.69648	2.85506
	LN(shear stress)	-3.61007	-2.0878	-1.26394	-0.96903	-0.2767	0.245351	0.499617	0.556755	0.991947	1.049093
	shear rate	1.562967	3.125935	5.209891	10.41978	52.09891	104.1978	156.2967	173.663	312.5935	347.3261
	Vicosity	0.017307	0.039655	0.054231	0.036416	0.014555	0.012266	0.010545	0.010048	0.008626	0.00822
150ppm	Dail Reading	4.7	5.4	8.4	9.1	14	19.1	23	24.4	34.2	36.7
	Shear stress	0.04467	0.10634	0.37064	0.43231	0.864	1.31331	1.6569	1.78024	2.64362	2.86387
	LN(shear stress)	-3.10845	-2.24111	-0.99252	-0.83861	-0.14618	0.272551	0.504948	0.576748	0.972149	1.052174
	shear rate	1.573682	3.147364	5.245606	10.49121	52.45606	104.9121	157.3682	174.8535	314.7364	349.7071
	Vicosity	0.028386	0.033787	0.070657	0.041207	0.016471	0.012518	0.010529	0.010181	0.008399	0.008189

Viscosity	700ppmCMC + Alfonic									
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Readin	4.7	5.4	6.8	7.5	14.9	24.4	30.3	31.6	43.4	47.9
	Shear stres	0.04467	0.10634	0.22968	0.29135	0.94329	1.78024	2.30003	2.41456	3.45414	3.85059
	LN(shear st	-3.10845	-2.24111	-1.47107	-1.23323	-0.05838	0.576748	0.832922	0.881517	1.239574	1.348226
	shear rate	1.559473	3.118945	5.198242	10.39648	51.98242	103.9648	155.9473	173.2747	311.8945	346.5495
	Vicosity	0.028644	0.034095	0.044184	0.028024	0.018146	0.017123	0.014749	0.013935	0.011075	0.011111
2ppm	Dail Readin	4.5	5	6.9	7.4	16.7	26	33.1	34	48.6	50.6
	Shear stres	0.02705	0.0711	0.23849	0.28254	1.10187	1.9212	2.54671	2.626	3.91226	4.08846
	LN(shear st	-3.61007	-2.64367	-1.43343	-1.26394	0.097009	0.65295	0.934802	0.965462	1.364115	1.408168
	shear rate	1.543132	3.086265	5.143774	10.28755	51.43774	102.8755	154.3132	171.4591	308.6265	342.9183
	Vicosity	0.017529	0.023038	0.046365	0.027464	0.021421	0.018675	0.016504	0.015316	0.012676	0.011923
5ppm	Dail Readin	4.7	5.2	6.5	7.4	15.1	23	29.6	31.4	43.5	46.8
	Shear stres	0.04467	0.08872	0.20325	0.28254	0.96091	1.6569	2.23836	2.39694	3.46295	3.75368
	LN(shear st	-3.10845	-2.42227	-1.59332	-1.26394	-0.03987	0.504948	0.805743	0.874193	1.242121	1.322737
	shear rate	1.556192	3.112383	5.187306	10.37461	51.87306	103.7461	155.6192	172.9102	311.2383	345.8204
	Vicosity	0.028705	0.028505	0.039182	0.027234	0.018524	0.015971	0.014384	0.013862	0.011126	0.010854
7ppm	Dail Readin	4.6	4.9	5.6	6.9	14.2	21.3	27.2	28.9	41	43.5
	Shear stres	0.03586	0.06229	0.12396	0.23849	0.88162	1.50713	2.02692	2.17669	3.2427	3.46295
	LN(shear st	-3.32813	-2.77595	-2.0878	-1.43343	-0.12599	0.410207	0.706517	0.777805	1.176406	1.242121
	shear rate	1.551864	3.103727	5.172879	10.34576	51.72879	103.4576	155.1864	172.4293	310.3727	344.8586
	Vicosity	0.023108	0.020069	0.023963	0.023052	0.017043	0.014568	0.013061	0.012624	0.010448	0.010042
10ppm	Dail Readin	4.3	5.3	6.2	7.1	15.3	23.6	32.3	32.9	46.4	48
	Shear stres	0.00943	0.09753	0.17682	0.25611	0.97853	1.70976	2.47623	2.52909	3.71844	3.8594
	LN(shear st	-4.66386	-2.3276	-1.73262	-1.36215	-0.0217	0.536353	0.906737	0.92786	1.313304	1.350512
	shear rate	1.530498	3.060996	5.101661	10.20332	51.01661	102.0332	153.0498	170.0554	306.0996	340.1107
	Vicosity	0.006161	0.031862	0.034659	0.025101	0.019181	0.016757	0.016179	0.014872	0.012148	0.011347
20ppm	Dail Readin	4.6	5.5	6	7.2	15.8	24.3	31.1	32.2	45.3	47.6
	Shear stres	0.03586	0.11515	0.1592	0.26492	1.02258	1.77143	2.37051	2.46742	3.62153	3.82416
	LN(shear st	-3.32813	-2.16152	-1.83759	-1.32833	0.022329	0.571787	0.863105	0.903173	1.286897	1.341339
	shear rate	1.551993	3.103985	5.173309	10.34662	51.73309	103.4662	155.1993	172.4436	310.3985	344.8873
	Vicosity	0.023106	0.037097	0.030773	0.025605	0.019766	0.017121	0.015274	0.014309	0.011667	0.011088
50ppm	Dail Readin	4.8	5.8	6	7.2	15.2	23.2	30	31	42.8	45.4
	Shear stres	0.05348	0.14158	0.1592	0.26492	0.96972	1.67452	2.2736	2.3617	3.40128	3.63034
	LN(shear st	-2.92845	-1.95489	-1.83759	-1.32833	-0.03075	0.515527	0.821364	0.859382	1.224152	1.289326
	shear rate	1.5622	3.124401	5.207334	10.41467	52.07334	104.1467	156.22	173.5778	312.4401	347.1556
	Vicosity	0.034234	0.045314	0.030572	0.025437	0.018622	0.016078	0.014554	0.013606	0.010886	0.010457
70ppm	Dail Readin	4.6	4.9	6	6.9	13.1	19.9	25.2	27	38.5	40.4
	Shear stres	0.03586	0.06229	0.1592	0.23849	0.78471	1.38379	1.85072	2.0093	3.02245	3.18984
	LN(shear st	-3.32813	-2.77595	-1.83759	-1.43343	-0.24244	0.324826	0.615575	0.697786	1.106068	1.159971
	shear rate	1.555397	3.110794	5.184657	10.36931	51.84657	103.6931	155.5397	172.8219	311.0794	345.6438
	Vicosity	0.023055	0.020024	0.030706	0.023	0.015135	0.013345	0.011899	0.011626	0.009716	0.009229
100ppm	Dail Readin	4.4	5	5.9	7.6	15.3	22	29.3	30.8	44	45.3
	Shear stres	0.01824	0.0711	0.15039	0.30016	0.97853	1.5688	2.21193	2.34408	3.507	3.62153
	LN(shear st	-4.00414	-2.64367	-1.89452	-1.20344	-0.0217	0.450311	0.793865	0.851893	1.254761	1.286897
	shear rate	1.544763	3.089527	5.149211	10.29842	51.49211	102.9842	154.4763	171.6404	308.9527	343.2807
	Vicosity	0.011808	0.023013	0.029206	0.029146	0.019003	0.015233	0.014319	0.013657	0.011351	0.01055
150ppm	Dail Readin	4.6	4.9	5.6	6.9	14.2	21.3	27.2	28.9	41	43.5
	Shear stres	0.03586	0.06229	0.12396	0.23849	0.88162	1.50713	2.02692	2.17669	3.2427	3.46295
	LN(shear st	-3.32813	-2.77595	-2.0878	-1.43343	-0.12599	0.410207	0.706517	0.777805	1.176406	1.242121
	shear rate	1.551864	3.103727	5.172879	10.34576	51.72879	103.4576	155.1864	172.4293	310.3727	344.8586
	Vicosity	0.023108	0.020069	0.023963	0.023052	0.017043	0.014568	0.013061	0.012624	0.010448	0.010042

Viscosity	1000ppm CMC +Alfonic										
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reading	4.4	5.1	7	8.2	18.9	27.3	36.7	39	57.3	60
	Shear stress	0.01824	0.07991	0.2473	0.35302	1.29569	2.03573	2.86387	3.0665	4.67873	4.9166
	LN(shear stress)	-4.00414	-2.52685	-1.39715	-1.04123	0.259043	0.710854	1.052174	1.120537	1.543027	1.592617
	shear rate	1.540505	3.081011	5.135018	10.27004	51.35018	102.7004	154.0505	171.1673	308.1011	342.3345
	Vicosity	0.01184	0.025936	0.04816	0.034374	0.025232	0.019822	0.01859	0.017915	0.015186	0.014362
2ppm	Dail Reading	4.3	5	6.9	7.8	17	25.7	33.8	36	50.2	54.1
	Shear stress	0.00943	0.0711	0.23849	0.31778	1.1283	1.89477	2.60838	2.8022	4.05322	4.39681
	LN(shear stress)	-4.66386	-2.64367	-1.43343	-1.1464	0.120712	0.639097	0.958729	1.030405	1.399512	1.480879
	shear rate	1.53337	3.06674	5.111233	10.22247	51.11233	102.2247	153.337	170.3744	306.674	340.7489
	Vicosity	0.00615	0.023184	0.04666	0.031086	0.022075	0.018535	0.017011	0.016447	0.013217	0.012903
5ppm	Dail Reading	4.7	4.9	7.2	8	15.8	26.2	35	36.9	52	54.1
	Shear stress	0.04467	0.06229	0.26492	0.3354	1.02258	1.93882	2.7141	2.88149	4.2118	4.39681
	LN(shear stress)	-3.10845	-2.77595	-1.32833	-1.09243	0.022329	0.66208	0.99846	1.058308	1.43789	1.480879
	shear rate	1.551318	3.102637	5.171061	10.34212	51.71061	103.4212	155.1318	172.3687	310.2637	344.7374
	Vicosity	0.028795	0.020076	0.051231	0.03243	0.019775	0.018747	0.017495	0.016717	0.013575	0.012754
7ppm	Dail Reading	4.2	4.8	7.1	7.9	15.8	24.7	33.2	35.7	52.1	54.3
	Shear stress	0.00062	0.05348	0.25611	0.32659	1.02258	1.80667	2.55552	2.77577	4.22061	4.41443
	LN(shear stress)	-7.38579	-2.92845	-1.36215	-1.11905	0.022329	0.591485	0.938256	1.020928	1.43998	1.484879
	shear rate	1.551913	3.103827	5.173044	10.34609	51.73044	103.4609	155.1913	172.4348	310.3827	344.8696
	Vicosity	0.0004	0.01723	0.049509	0.031567	0.019767	0.017462	0.016467	0.016098	0.013598	0.0128
10ppm	Dail Reading	6.5	8	8.3	8.6	16.8	25.1	33	36	52	54.2
	Shear stress	0.20325	0.3354	0.36183	0.38826	1.11068	1.84191	2.5379	2.8022	4.2118	4.40562
	LN(shear stress)	-1.59332	-1.09243	-1.01658	-0.94608	0.104972	0.610803	0.931337	1.030405	1.43789	1.482881
	shear rate	1.598415	3.19683	5.32805	10.6561	53.2805	106.561	159.8415	177.6017	319.683	355.2033
	Vicosity	0.127157	0.104916	0.06791	0.036435	0.020846	0.017285	0.015878	0.015778	0.013175	0.012403
20ppm	Dail Reading	4.5	5	6.8	8	15.1	29	34.8	34.7	51.1	53
	Shear stress	0.02705	0.0711	0.22968	0.3354	0.96091	2.1855	2.69648	2.68767	4.13251	4.2999
	LN(shear stress)	-3.61007	-2.64367	-1.47107	-1.09243	-0.03987	0.781845	0.991947	0.988675	1.418885	1.458592
	shear rate	1.546544	3.093088	5.155146	10.31029	51.55146	103.1029	154.6544	171.8382	309.3088	343.6764
	Vicosity	0.017491	0.022987	0.044554	0.032531	0.01864	0.021197	0.017436	0.015641	0.01336	0.012511
30ppm	Dail Reading	4.8	5.1	7.3	8.9	17.2	25.2	32.9	35	49.9	52.4
	Shear stress	0.05348	0.07991	0.27373	0.41469	1.14592	1.85072	2.52909	2.7141	4.02679	4.24704
	LN(shear stress)	-2.92845	-2.52685	-1.29561	-0.88022	0.136208	0.615575	0.92786	0.99846	1.39297	1.446222
	shear rate	1.558687	3.117374	5.195623	10.39125	51.95623	103.9125	155.8687	173.1874	311.7374	346.3749
	Vicosity	0.034311	0.025634	0.052685	0.039908	0.022055	0.01781	0.016226	0.015671	0.012917	0.012261
40ppm	Dail Reading	4.2	5.1	7	9	16.9	26	34	35.3	50.9	53.2
	Shear stress	0.00062	0.07991	0.2473	0.4235	1.11949	1.9212	2.626	2.74053	4.11489	4.31752
	LN(shear stress)	-7.38579	-2.52685	-1.39715	-0.8592	0.112873	0.65295	0.965462	1.008151	1.414612	1.462681
	shear rate	1.561872	3.123743	5.206239	10.41248	52.06239	104.1248	156.1872	173.5413	312.3743	347.0826
	Vicosity	0.000397	0.025581	0.047501	0.040672	0.021503	0.018451	0.016813	0.015792	0.013173	0.012439
50ppm	Dail Reading	4.6	5.2	6.1	8.3	15	23.7	33.1	34	49.2	51.5
	Shear stress	0.03586	0.08872	0.16801	0.36183	0.9521	1.71857	2.54671	2.626	3.96512	4.16775
	LN(shear stress)	-3.32813	-2.42227	-1.78373	-1.01658	-0.04909	0.541493	0.934802	0.965462	1.377536	1.427376
	shear rate	1.552508	3.105017	5.175028	10.35006	51.75028	103.5006	155.2508	172.5009	310.5017	345.0019
	Vicosity	0.023098	0.028573	0.032466	0.034959	0.018398	0.016604	0.016404	0.015223	0.01277	0.01208
70ppm	Dail Reading	4.7	5.7	6.4	8	14.6	23.9	35	36.8	51	54.2
	Shear stress	0.04467	0.13277	0.19444	0.3354	0.91686	1.73619	2.7141	2.87268	4.1237	4.40562
	LN(shear stress)	-3.10845	-2.01914	-1.63763	-1.09243	-0.0868	0.551693	0.99846	1.055245	1.416751	1.482881
	shear rate	1.557931	3.115862	5.193104	10.38621	51.93104	103.8621	155.7931	173.1035	311.5862	346.2069
	Vicosity	0.028673	0.042611	0.037442	0.032293	0.017655	0.016716	0.017421	0.016595	0.013235	0.012725
100ppm	Dail Reading	4.9	5.6	6.5	8.6	15.9	25.1	33	36.7	52.4	53.7
	Shear stress	0.06229	0.12396	0.20325	0.38826	1.03139	1.84191	2.5379	2.86387	4.24704	4.36157
	LN(shear stress)	-2.77595	-2.0878	-1.59332	-0.94608	0.030907	0.610803	0.931337	1.052174	1.446222	1.472832
	shear rate	1.563027	3.126054	5.21009	10.42018	52.1009	104.2018	156.3027	173.6697	312.6054	347.3394
	Vicosity	0.039852	0.039654	0.039011	0.03726	0.019796	0.017676	0.016237	0.01649	0.013586	0.012557
150ppm	Dail Reading	4.3	5	6	7.6	16	24	31	32.8	47.8	50.8
	Shear stress	0.00943	0.0711	0.1592	0.30016	1.0402	1.745	2.3617	2.52028	3.84178	4.10608
	LN(shear stress)	-4.66386	-2.64367	-1.83759	-1.20344	0.039413	0.556755	0.859382	0.92437	1.345936	1.412469
	shear rate	1.534226	3.068452	5.114087	10.22817	51.14087	102.2817	153.4226	170.4696	306.8452	340.9392
	Vicosity	0.006146	0.023171	0.03113	0.029346	0.02034	0.017061	0.015393	0.014784	0.01252	0.012043

Flow Data

100ppm CMC +100ppm Alfonic 1412-9 in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in volumetric
1.027	1	2	1.029	0.048218	0.127048	313.3944	0.023641	0.985617	0.122456	4.83631E-05
1.047	1	2	1.083	0.078898	0.207885	634.1078	0.030234	1.260504	0.058493	7.91354E-05
1.058	1	2	1.082	0.095772	0.252345	836.8178	0.030112	1.255413	0.039537	9.60602E-05
1.145	1	2	1.178	0.22923	0.603988	2918.118	0.041834	1.744101	0.009588	0.00022992
1.186	1	2	1.303	0.292124	0.769705	4128.593	0.057096	2.380412	0.008058	0.000293003
1.247	1	2	1.495	0.385698	1.016259	6144.967	0.08054	3.357787	0.00652	0.000386859
1.318	1	2	1.787	0.494612	1.303232	8772.307	0.116193	4.844211	0.00572	0.0004961
1.377	1	2	2.058	0.585118	1.541702	11157.35	0.149282	6.223735	0.005251	0.000586879
1.447	1	2	2.425	0.692498	1.824633	14200.03	0.194093	8.091946	0.004874	0.000694582
1.528	1	2	2.908	0.816752	2.152024	17983.15	0.253067	10.55065	0.004569	0.00081921
1.579	1	2	3.259	0.894986	2.35816	20498.48	0.295924	12.33742	0.004449	0.000897679
1.661	1	2	3.833	1.020774	2.689593	24743.57	0.366009	15.25936	0.00423	0.001023846
1.715	1	2	4.217	1.10361	2.907854	27666.87	0.412896	17.21411	0.004083	0.001106931
1.75	1	2	4.575	1.1573	3.04932	29613.25	0.456608	19.03651	0.004106	0.001160782
1.791	1	2	4.858	1.220194	3.215036	31943.26	0.491162	20.47712	0.003973	0.001223866
1.91	1	3	1.493	1.40274	3.696019	38997.43	0.596043	24.84975	0.003648	0.001406961
2.023	1	3	1.61	1.576082	4.15275	46074.12	0.743241	30.9866	0.003603	0.001580824
2.115	1	3	1.707	1.71721	4.524602	52090.86	0.865277	36.07441	0.003534	0.001722377
2.211	1	3	1.811	1.864474	4.912622	58600.66	0.996119	41.52938	0.003451	0.001870084
2.306	1	3	1.929	2.010204	5.296599	65264.88	1.144575	47.71868	0.003411	0.002016253
2.455	1	3	2.12	2.23877	5.898838	76140.52	1.384872	57.73695	0.003328	0.002245507
2.62	1	3	2.351	2.49188	6.565747	88754.81	1.675493	69.85329	0.00325	0.002499378
2.802	1	3	2.633	2.771068	7.301367	103323.5	2.030277	84.64466	0.003184	0.002779406
3.016	1	3	2.988	3.099344	8.166327	121279.6	2.476903	103.265	0.003105	0.00310867
3.207	1	3	3.317	3.392338	8.938324	138017	2.890818	120.5216	0.003025	0.003402546
3.383	1	3	3.653	3.662322	9.649694	154003.5	3.313539	138.1454	0.002975	0.003673342
3.487	1	3	3.847	3.821858	10.07005	163694.3	3.557611	148.321	0.002933	0.003833358
3.568	1	3	4.021	3.946112	10.39744	171364.1	3.77652	157.4476	0.002921	0.003957986
3.684	1	3	4.293	4.124056	10.8663	182530.2	4.118723	171.7145	0.002916	0.004136465
3.788	1	3	4.498	4.283592	11.28665	192719.7	4.376634	182.467	0.002872	0.004296481

100ppm CMC +100ppm Alfonic 1412-9 in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in volumetric
1.024	2	2	1.01	0.043616	0.045948	80.20876	0.021321	0.419596	0.398083	4.37472E-05
1.076	2	2	1.029	0.123384	0.129982	381.8672	0.023641	0.465251	0.055157	0.000123755
1.143	2	2	1.044	0.226162	0.238256	948.0067	0.025472	0.501295	0.017688	0.000226843
1.152	2	2	1.089	0.239968	0.2528	1036.161	0.030967	0.609426	0.019101	0.00024069
1.23	2	2	1.196	0.35962	0.37885	1901.378	0.044032	0.866539	0.012093	0.000360702
1.329	2	2	1.348	0.511486	0.538837	3225.858	0.062591	1.231782	0.008498	0.000513025
1.391	2	2	1.433	0.606594	0.639031	4166.642	0.072969	1.43603	0.007044	0.000608419
1.456	2	2	1.574	0.706304	0.744073	5235.597	0.090185	1.774842	0.006421	0.000708429
1.552	2	2	1.806	0.853568	0.899212	6956.411	0.118513	2.332319	0.005778	0.000856136
1.714	2	2	2.253	1.102076	1.161008	10207.32	0.173091	3.406424	0.005062	0.001105392
1.799	2	2	2.525	1.232466	1.298371	12072.19	0.206303	4.060018	0.004824	0.001236175
1.886	2	2	2.842	1.365924	1.438965	14086.09	0.245008	4.821743	0.004664	0.001370034
2.054	2	2	3.5	1.623636	1.710458	18256.97	0.32535	6.402864	0.004384	0.001628522
2.148	2	2	3.912	1.767832	1.862365	20743.37	0.375655	7.392866	0.004269	0.001773151
2.235	2	2	4.253	1.90129	2.002959	23137.12	0.417291	8.212262	0.0041	0.001907011
2.311	2	2	4.665	2.017874	2.125778	25298.41	0.467597	9.202264	0.004079	0.002023946
2.464	2	3	1.442	2.252576	2.37303	29840.09	0.53188	10.46736	0.003723	0.002259354
2.597	2	3	1.516	2.456598	2.587962	33986.36	0.62498	12.29955	0.003678	0.00246399
2.78	2	3	1.613	2.73732	2.883695	39977.91	0.747015	14.70121	0.003541	0.002745557
2.904	2	3	1.69	2.927536	3.084083	44218.35	0.843889	16.60767	0.003497	0.002936345
3.026	2	3	1.776	3.114684	3.281238	48527.32	0.952086	18.73697	0.003486	0.003124056
3.206	2	3	1.895	3.390804	3.572124	55124.1	1.1018	21.68333	0.003404	0.003401007
3.512	2	3	2.12	3.860208	4.066628	66963.37	1.384872	27.25418	0.003301	0.003871823
3.727	2	3	2.287	4.190018	4.414075	75729.74	1.594975	31.38898	0.003227	0.004202626
4.04	2	3	2.551	4.67016	4.919892	89118.64	1.927113	37.92544	0.003138	0.004684213
4.326	2	3	2.825	5.108884	5.382076	101972.6	2.271833	44.70949	0.003092	0.005124257
4.547	2	3	3.025	5.447898	5.739218	112293.5	2.523453	49.66136	0.00302	0.005464291
4.782	2	3	3.25	5.808388	6.118985	123626.4	2.806525	55.2322	0.002955	0.005825866
5.072	2	3	3.548	6.253248	6.587634	138103.7	3.181439	62.61048	0.00289	0.006272064

100ppm CMC +300ppm Alfonic 1412-9 in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in volumetric
1.059	1	2	1.023	0.097306	0.256028	840.2997	0.022908	0.955074	0.029184	9.75988E-05
1.09	1	2	1.109	0.14486	0.38115	1526.691	0.033409	1.392857	0.019204	0.000145296
1.168	1	2	1.241	0.264512	0.695974	3768.369	0.049526	2.064802	0.008538	0.000265308
1.205	1	2	1.361	0.32127	0.845314	5044.769	0.064178	2.675661	0.0075	0.000322237
1.258	1	2	1.537	0.402572	1.059232	7077.178	0.085668	3.571588	0.006376	0.000403783
1.327	1	2	1.837	0.508418	1.33773	10045.86	0.122298	5.098736	0.005707	0.000509948
1.404	1	2	2.217	0.626536	1.648518	13744.5	0.168696	7.033123	0.005184	0.000628421
1.519	1	2	2.893	0.802946	2.112681	19943.63	0.251235	10.4743	0.0047	0.000805362
1.584	1	2	3.324	0.902656	2.375034	23773.25	0.30386	12.6683	0.004498	0.000905372
1.694	1	2	4.156	1.071396	2.819017	30745.03	0.405448	16.90359	0.004261	0.00107462
1.734	1	2	4.487	1.132756	2.980465	33424.81	0.445863	18.58854	0.004191	0.001136164
1.79	1	2	4.977	1.21866	3.206492	37299.86	0.505692	21.08289	0.004107	0.001222327
1.884	1	3	1.485	1.362856	3.585895	44115.12	0.585979	24.43014	0.003806	0.001366957
2.01	1	3	1.604	1.55614	4.094457	53829.47	0.735692	30.67189	0.003665	0.001560822
2.033	1	3	1.628	1.591422	4.18729	55671.25	0.765887	31.93073	0.003648	0.001596211
2.119	1	3	1.725	1.723346	4.534403	62738.25	0.887923	37.01854	0.003606	0.001728532
2.197	1	3	1.82	1.842998	4.849227	69387.06	1.007442	42.00145	0.003578	0.001848544
2.29	1	3	1.933	1.98566	5.224594	77601.11	1.149607	47.92849	0.003517	0.001991635
2.414	1	3	2.101	2.175876	5.725083	89019.61	1.360968	56.74037	0.003467	0.002182423
2.611	1	3	2.375	2.478074	6.520215	108203.1	1.705688	71.11213	0.00335	0.002485531
2.815	1	3	2.703	2.79101	7.3436	129342.6	2.118344	88.31628	0.00328	0.002799408
3.084	1	3	3.171	3.203656	8.429339	159075.8	2.707135	112.8637	0.003182	0.003213296
3.304	1	3	3.581	3.541136	9.317304	184873.8	3.222956	134.3689	0.0031	0.003551791
3.509	1	3	4.015	3.855606	10.14473	210049.9	3.768972	157.1329	0.003058	0.003867208
3.599	1	3	4.174	3.993666	10.50798	221437.1	3.969009	165.4727	0.003002	0.004005683
3.707	1	3	4.435	4.159338	10.94389	235363.8	4.297374	179.1626	0.002996	0.004171854
3.764	1	3	4.564	4.246776	11.17396	242827.4	4.459668	185.9289	0.002983	0.004259555

100ppm CMC +300ppm Alfonic 1412-9 in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in volumetric
1.024	2	2	1.01	0.043616	0.045948	80.20876	0.021321	0.419596	0.398083	4.37472E-05
1.076	2	2	1.029	0.123384	0.129982	381.8672	0.023641	0.465251	0.055157	0.000123755
1.143	2	2	1.044	0.226162	0.238256	948.0067	0.025472	0.501295	0.017688	0.000226843
1.152	2	2	1.089	0.239968	0.2528	1036.161	0.030967	0.609426	0.019101	0.00024069
1.23	2	2	1.196	0.35962	0.37885	1901.378	0.044032	0.866539	0.012093	0.000360702
1.329	2	2	1.348	0.511486	0.538837	3225.858	0.062591	1.231782	0.008498	0.000513025
1.391	2	2	1.433	0.606594	0.639031	4166.642	0.072969	1.43603	0.007044	0.000608419
1.456	2	2	1.574	0.706304	0.744073	5235.597	0.090185	1.774842	0.006421	0.000708429
1.552	2	2	1.806	0.853568	0.899212	6956.411	0.118513	2.332319	0.005778	0.000856136
1.714	2	2	2.253	1.102076	1.161008	10207.32	0.173091	3.406424	0.005062	0.001105392
1.799	2	2	2.525	1.232466	1.298371	12072.19	0.206303	4.060018	0.004824	0.001236175
1.886	2	2	2.842	1.365924	1.438965	14086.09	0.245008	4.821743	0.004664	0.001370034
2.054	2	2	3.5	1.623636	1.710458	18256.97	0.32535	6.402864	0.004384	0.001628522
2.148	2	2	3.912	1.767832	1.862365	20743.37	0.375655	7.392866	0.004269	0.001773151
2.235	2	2	4.253	1.90129	2.002959	23137.12	0.417291	8.212262	0.0041	0.001907011
2.311	2	2	4.665	2.017874	2.125778	25298.41	0.467597	9.202264	0.004079	0.002023946
2.464	2	3	1.442	2.252576	2.37303	29840.09	0.53188	10.46736	0.003723	0.002259354
2.597	2	3	1.516	2.456598	2.587962	33986.36	0.62498	12.29955	0.003678	0.00246399
2.78	2	3	1.613	2.73732	2.883695	39977.91	0.747015	14.70121	0.003541	0.002745557
2.904	2	3	1.69	2.927536	3.084083	44218.35	0.843889	16.60767	0.003497	0.002936345
3.026	2	3	1.776	3.114684	3.281238	48527.32	0.952086	18.73697	0.003486	0.003124056
3.206	2	3	1.895	3.390804	3.572124	55124.1	1.1018	21.68333	0.003404	0.003401007
3.512	2	3	2.12	3.860208	4.066628	66963.37	1.384872	27.25418	0.003301	0.003871823
3.727	2	3	2.287	4.190018	4.414075	75729.74	1.594975	31.38898	0.003227	0.004202626
4.04	2	3	2.551	4.67016	4.919892	89118.64	1.927113	37.92544	0.003138	0.004684213
4.326	2	3	2.825	5.108884	5.382076	101972.6	2.271833	44.70949	0.003092	0.005124257
4.547	2	3	3.025	5.447898	5.739218	112293.5	2.523453	49.66136	0.00302	0.005464291
4.782	2	3	3.25	5.808388	6.118985	123626.4	2.806525	55.2322	0.002955	0.005825866
5.072	2	3	3.548	6.253248	6.587634	138103.7	3.181439	62.61048	0.00289	0.006272064

100ppm CMC +500ppm Alfonic in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in volumetric
1.04	1	2	1.037	0.06816	0.179143	536.488	0.024618	1.026341	0.063988	6.83651E-05
1.106	1	2	1.114	0.169404	0.445239	2071.879	0.034019	1.418309	0.014315	0.000169914
1.169	1	2	1.242	0.266046	0.69924	4048.527	0.049648	2.069892	0.00847	0.000266847
1.237	1	2	1.439	0.370358	0.9734	6614.702	0.073702	3.072719	0.006488	0.000371472
1.306	1	2	1.708	0.476204	1.251591	9605.753	0.106547	4.442062	0.005674	0.000477637
1.381	1	2	2.083	0.591254	1.553973	13243.68	0.152334	6.350997	0.005262	0.000593033
1.462	1	2	2.518	0.715508	1.880546	17577.3	0.205448	8.565362	0.004846	0.000717661
1.558	1	2	3.144	0.862772	2.267595	23205.03	0.281882	11.75201	0.004573	0.000865368
1.658	1	2	3.904	1.016172	2.670771	29584.13	0.374678	15.62079	0.004382	0.00101923
1.719	1	2	4.381	1.109746	2.916709	33715.93	0.43292	18.04895	0.004245	0.001113085
1.823	1	3	1.431	1.269282	3.336012	41153.75	0.518041	21.59775	0.003883	0.001273101
1.907	1	3	1.511	1.398138	3.67468	47503.94	0.618689	25.79388	0.003822	0.001402345
1.962	1	3	1.568	1.482508	3.896427	51819.77	0.690401	28.78363	0.003793	0.001486969
1.985	1	3	1.599	1.51779	3.989157	53660.54	0.729402	30.40963	0.003823	0.001522357
2.07	1	3	1.7	1.64818	4.331857	60642.26	0.85647	35.70725	0.003807	0.001653139
2.145	1	3	1.776	1.76323	4.634239	67029.49	0.952086	39.69358	0.003698	0.001768536
2.221	1	3	1.875	1.879814	4.940653	73711.06	1.076638	44.88629	0.003679	0.00188547
2.442	1	3	2.19	2.218828	5.831672	94275.94	1.472939	61.40857	0.003613	0.002225505
2.498	1	3	2.274	2.304732	6.057451	99743.31	1.578619	65.81451	0.003589	0.002311667
2.708	1	3	2.617	2.626872	6.904121	121117.8	2.010148	83.80544	0.003518	0.002634776
2.828	1	3	2.818	2.810952	7.387932	133925.2	2.263026	94.34822	0.003459	0.00281941
3.018	1	3	3.15	3.102412	8.153967	155042.2	2.680715	111.7622	0.003363	0.003111747
3.248	1	3	3.617	3.455232	9.081272	181916.8	3.268248	136.2571	0.003306	0.003465629
3.379	1	3	3.886	3.656186	9.609433	197837.7	3.606677	150.3666	0.003258	0.003667188
3.559	1	3	4.28	3.932306	10.33515	220411.8	4.102368	171.0326	0.003204	0.003944138
3.72	1	3	4.65	4.17928	10.98426	241265.6	4.567865	190.4397	0.003158	0.004191856

100ppm CMC +500ppm Alfonic in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in volumetric
1.047	2	2	1.022	0.078898	0.083026	216.9854	0.022786	0.448431	0.13016	7.91354E-05
1.099	2	2	1.043	0.158666	0.166967	611.9741	0.02535	0.498892	0.035806	0.000159143
1.132	2	2	1.075	0.209288	0.220237	923.021	0.029258	0.575785	0.023751	0.000209918
1.188	2	2	1.112	0.295192	0.310635	1537.719	0.033775	0.664693	0.013782	0.00029608
1.255	2	2	1.216	0.39797	0.41879	2395.702	0.046474	0.914597	0.010434	0.000399168
1.322	2	2	1.304	0.500748	0.526944	3368.991	0.057218	1.126054	0.008114	0.000502255
1.411	2	2	1.483	0.637274	0.670613	4818.318	0.079074	1.556176	0.006923	0.000639192
1.536	2	2	1.765	0.829024	0.872394	7119.35	0.113507	2.233799	0.005872	0.000831519
1.625	2	2	1.993	0.96555	1.016062	8926.868	0.141345	2.781665	0.005391	0.000968455
1.737	2	2	2.33	1.137358	1.196858	11382.87	0.182493	3.591449	0.005016	0.00114078
1.894	2	2	2.7	1.378196	1.450296	15137.23	0.22767	4.480529	0.004262	0.001382343
1.952	2	2	3.105	1.467168	1.543922	16609.92	0.277121	5.453711	0.004578	0.001471583
2.136	2	2	3.887	1.749424	1.840944	21566.29	0.372603	7.332793	0.004329	0.001754688
2.325	2	2	4.765	2.03935	2.146038	27077.69	0.479807	9.442556	0.004102	0.002045486
2.45	2	3	1.438	2.2311	2.347819	30940.83	0.526848	10.36833	0.003763	0.002237813
2.588	2	3	1.521	2.442792	2.570586	35396.25	0.63127	12.42335	0.003762	0.002450142
2.663	2	3	1.566	2.557842	2.691655	37898.35	0.687885	13.53752	0.003739	0.002565539
2.774	2	3	1.636	2.728116	2.870836	41702.2	0.775952	15.27067	0.003707	0.002736325
2.926	2	3	1.726	2.961284	3.116202	47099.73	0.889181	17.49901	0.003606	0.002970195
3.158	2	3	1.897	3.317172	3.490709	55739.96	1.104316	21.73285	0.003569	0.003327153
3.37	2	3	2.051	3.64238	3.83293	64039.33	1.298063	25.54578	0.003479	0.00365334
3.64	2	3	2.27	4.05656	4.268777	75138.42	1.573587	30.96807	0.0034	0.004068766
3.843	2	3	2.462	4.367962	4.59647	83855.73	1.815142	35.72186	0.003383	0.004381105
4.242	2	3	2.836	4.980028	5.240556	101872.4	2.285672	44.98185	0.003277	0.004995013
4.526	2	3	3.094	5.415684	5.699003	115374.5	2.610261	51.36975	0.003165	0.00543198
4.679	2	3	3.265	5.650386	5.945984	122872.3	2.825397	55.60359	0.003147	0.005667388
4.853	2	3	3.446	5.917302	6.226863	131584.2	3.053113	60.08503	0.0031	0.005935107
5.044	2	3	3.684	6.210296	6.535185	141368.6	3.35254	65.97774	0.003091	0.006228983

500ppm CMC +20ppm Alfonic 1412-9 in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in volumetric
1.051	1	2	1.093	0.085034	0.224074876	365.2937998	0.0314553	1.311408696	0.052394605	8.52899E-05
1.074	1	2	1.112	0.120316	0.317047214	577.4127122	0.0337752	1.408128074	0.028101475	0.000120678
1.09	1	2	1.163	0.14486	0.381723622	737.6442602	0.0400023	1.667743245	0.022959687	0.000145296
1.171	1	2	1.346	0.269114	0.709147942	1669.920081	0.0623466	2.599303565	0.010368553	0.000269924
1.227	1	2	1.538	0.355018	0.935515373	2406.656031	0.0857898	3.576678326	0.008198093	0.000356086
1.281	1	2	1.763	0.437854	1.153798253	3173.69635	0.1132623	4.722039375	0.007115488	0.000439172
1.339	1	2	2.022	0.526826	1.388250236	4050.858768	0.1448862	6.040477205	0.006287393	0.000528411
1.406	1	2	2.357	0.629604	1.659082698	5124.524208	0.1857897	7.745792545	0.005645009	0.000631498
1.446	1	2	2.569	0.690964	1.82077372	5793.397432	0.2116749	8.824977178	0.005339941	0.000693043
1.555	1	2	3.223	0.85817	2.261381755	7710.697511	0.2915283	12.15415996	0.004767734	0.000860752
1.607	1	2	3.548	0.937938	2.471580084	8669.935081	0.3312108	13.80857036	0.00453455	0.00094076
1.72	1	2	4.333	1.11128	2.928357222	10843.61502	0.4270593	17.8046078	0.00416504	0.001114624
1.744	1	3	1.378	1.148096	3.025371835	11320.01436	0.4513618	18.8178078	0.004124263	0.001151551
1.874	1	3	1.47	1.347516	3.550867657	13983.14601	0.567107	23.64336221	0.003761622	0.001351571
1.944	1	3	1.519	1.454896	3.833826946	15471.47214	0.6287539	26.21349446	0.003577624	0.001459274
1.977	1	3	1.536	1.505518	3.96722204	16185.53427	0.6501416	27.10517299	0.003454729	0.001510048
2.071	1	3	1.62	1.649714	4.347195942	18261.19675	0.755822	31.51111398	0.003344877	0.001654678
2.165	1	3	1.708	1.79391	4.727169844	20395.64997	0.8665348	36.12686168	0.003243117	0.001799308
2.287	1	3	1.819	1.981058	5.220327462	23248.26275	1.0061839	41.94899799	0.003087884	0.001987019
2.452	1	3	2.012	2.234168	5.887302928	27244.40518	1.2489972	52.07217192	0.003013754	0.002240891
2.613	1	3	2.195	2.481142	6.538109293	31285.86371	1.4792295	61.67082908	0.002894078	0.002488608
2.969	1	3	2.65	3.027246	7.97715939	40674.46748	2.051665	85.53634277	0.002696429	0.003036355
3.377	1	3	3.235	3.653118	9.626407816	52118.23327	2.7876535	116.2205746	0.002515877	0.00366411
3.613	1	3	3.618	4.015142	10.58038485	59037.22979	3.2695058	136.3095675	0.002442633	0.004027224
3.755	1	3	3.845	4.23297	11.15438798	63298.59448	3.5550945	148.2160985	0.002389674	0.004245707
3.876	1	3	4.055	4.418584	11.64350332	66985.56387	3.8192955	159.230951	0.002356107	0.00443188
3.986	1	3	4.276	4.587324	12.08815363	70380.59141	4.0973356	170.8227719	0.002345096	0.004601127

500ppm CMC +20ppm Alfonic 1412-9 in 1.5inch pipe											
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Blasius	FR in volumetric
1.011	2	2	1.025	0.023674	0.024977	27.60365	0.023153	0.455639	1.465074	0.202525	2.37452E-05
1.105	2	2	1.047	0.16787	0.177113	365.7732	0.025839	0.508504	0.032518	0.197042	0.000168375
1.178	2	2	1.127	0.279852	0.29526	717.8197	0.035607	0.700737	0.016124	0.181863	0.000280694
1.235	2	2	1.216	0.36729	0.387513	1027.513	0.046474	0.914597	0.012218	0.170147	0.000368395
1.333	2	2	1.401	0.517622	0.546122	1615.671	0.069062	1.359137	0.009142	0.154105	0.00051918
1.445	2	2	1.65	0.68943	0.727389	2358.108	0.099465	1.957464	0.007422	0.140673	0.000691505
1.538	2	2	1.891	0.832092	0.877906	3022.16	0.128891	2.536567	0.006602	0.131847	0.000834596
1.62	2	2	2.113	0.95788	1.01062	3638.924	0.155997	3.070015	0.00603	0.125704	0.000960762
1.724	2	2	2.449	1.117416	1.17894	4458.948	0.197023	3.877396	0.005596	0.118576	0.001120778
1.883	2	2	3.002	1.361322	1.436275	5785.602	0.264544	5.20621	0.005063	0.110155	0.001365418
2.023	2	2	3.533	1.576082	1.662859	7018.969	0.329379	6.48216	0.004703	0.10428	0.001580824
2.158	2	2	4.068	1.783172	1.881351	8260.408	0.394703	7.767722	0.004402	0.099669	0.001788538
2.33	2	2	4.855	2.04702	2.159727	9909.68	0.490796	9.658819	0.004154	0.094385	0.00205318
2.523	2	3	1.475	2.343082	2.472089	11842.71	0.573398	11.28442	0.003704	0.090785	0.002350132
2.565	2	3	1.494	2.40751	2.540065	12274.17	0.597301	11.75485	0.003655	0.089863	0.002414754
2.701	2	3	1.563	2.616134	2.760175	13696.34	0.68411	13.46324	0.003545	0.086865	0.002624006
2.876	2	3	1.65	2.884584	3.043406	15580.06	0.793565	15.6173	0.003382	0.083701	0.002893264
3.04	2	3	1.757	3.13616	3.308833	17397.06	0.928182	18.26655	0.003347	0.080486	0.003145597
3.356	2	3	1.936	3.620904	3.820267	21029.01	1.153382	22.69846	0.00312	0.076231	0.003631799
3.609	2	3	2.112	4.009006	4.229737	24052.12	1.374807	27.0561	0.003034	0.072957	0.004021069
3.904	2	3	2.289	4.461536	4.707183	27696.65	1.597491	31.4385	0.002846	0.07027	0.004474961
4.154	2	3	2.483	4.845036	5.111798	30879.57	1.841562	36.24181	0.002782	0.067816	0.004859615
4.491	2	3	2.723	5.361994	5.657219	35298.37	2.143506	42.18404	0.002644	0.06529	0.005378128
4.715	2	3	2.884	5.70561	6.019754	38312.55	2.34606	46.17029	0.002556	0.063833	0.005722778
4.951	2	3	3.082	6.067634	6.401711	41551.48	2.595164	51.07264	0.0025	0.062242	0.006085892
5.133	2	3	3.24	6.346822	6.696271	44091.99	2.793944	54.98461	0.00246	0.061104	0.00636592
5.135	2	3	3.303	6.34989	6.699508	44120.11	2.873204	56.54445	0.002527	0.060679	0.006368997

1.3 CMC-Alfonic 1412-3 Ethoxylate

Bench-scale

250ppm CMC +Alfonic 1412-3										
Surface tension										
Concentration	1	2	3	5	10	30	50	70	100	150
	66	61.8	50.2	49	40.3	34.8	32.1	30.3	29.2	29.8
	66.4	60.9	49.4	49.2	40.1	35	32.6	31	29.8	29.2
Avg.	66.2	61.35	49.8	49.1	40.2	34.9	32.35	30.65	29.5	29.5
Conductivity										
Concentration	1	2	3	5	10	30	50	70	100	150
	0.281	0.287	0.292	0.285	0.278	0.299	0.295	0.296	0.29	0.286
	0.281	0.285	0.291	0.285	0.278	0.298	0.299	0.292	0.29	0.288
Avg.	0.281	0.286	0.2915	0.285	0.278	0.2985	0.297	0.294	0.29	0.287

500ppm CMC +Alfonic 1412-3										
Surface tension										
Concentration	1	2	3	5	10	30	50	70	100	150
	56.6	51.2	45.9	40.9	35	32.7	30	29.3	29.1	28.9
	55.2	48.3	44.1	40.1	34.4	31.2	30.6	29	29	29
Avg.	55.9	49.75	45	40.5	34.7	31.95	30.3	29.15	29.05	28.95
Conductivity										
Concentration	1	2	3	5	10	30	50	70	100	150
	0.566	0.548	0.567	0.554	0.545	0.543	0.546	0.554	0.556	0.543
	0.568	0.549	0.567	0.555	0.543	0.543	0.548	0.555	0.548	0.542
Avg.	0.567	0.5485	0.567	0.5545	0.544	0.543	0.547	0.5545	0.552	0.5425

700ppm CMC +Alfonic 1412-3										
Surface tension										
Concentration	1	2	3	5	10	30	50	70	100	150
	63.3	56.8	51.5	49.1	42.1	34.7	31.1	30.6	30.8	29.9
	62.8	55	51.8	49	41.8	34.3	31.2	30.7	29.8	30
Avg.	63.05	55.9	51.65	49.05	41.95	34.5	31.15	30.65	30.3	29.95
Conductivity										
Concentration	1	2	3	5	10	30	50	70	100	150
	0.782	0.777	0.765	0.774	0.767	0.786	0.786	0.766	0.782	0.78
	0.783	0.771	0.769	0.78	0.765	0.781	0.79	0.766	0.786	0.779
Avg.	0.7825	0.774	0.767	0.777	0.766	0.7835	0.788	0.766	0.784	0.7795

1000ppm CMC +Alfonic 1412-3										
Surface tension										
Concentration	1	2	3	5	10	30	50	70	100	150
	58	55.9	49.3	42.1	36.8	32.2	28.5	29.1	28.9	29
	57.8	52.1	48.2	40.9	35.2	32.4	28.6	29.4	29.2	29
Avg.	57.9	54	48.75	41.5	36	32.3	28.55	29.25	29.05	29
Conductivity										
Concentration	1	2	3	5	10	30	50	70	100	150
	1.098	1.087	1.095	1.09	1.078	1.09	1.09	1.067	1.065	1.074
	1.095	1.084	1.084	1.089	1.082	1.081	1.095	1.071	1.071	1.073
Abg.	1.0965	1.0855	1.0895	1.0895	1.08	1.0855	1.0925	1.069	1.068	1.0735

250ppm CMC +Alfonic 1412-3											
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reac	5.1	5.5	5.7	6.4	10	13.7	16.8	17.5	23.9	25.8
	Shear str	0.07991	0.11515	0.13277	0.19444	0.5116	0.83757	1.11068	1.17235	1.73619	1.90358
	LN(shear	-2.52685	-2.16152	-2.01914	-1.63763	-0.67021	-0.17725	0.104972	0.15901	0.551693	0.643736
	shear rat	1.598476	3.196951	5.328252	10.6565	53.28252	106.565	159.8476	177.6084	319.6951	355.2168
	Vicosity	0.049991	0.036019	0.024918	0.018246	0.009602	0.00786	0.006948	0.006601	0.005431	0.005359
2ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.8	5.2	6.2	7.4	10.7	13.9	16.9	17.9	24.9	26.3
	Shear str	0.05348	0.08872	0.17682	0.28254	0.57327	0.85519	1.11949	1.20759	1.82429	1.94763
	LN(shear	-2.92845	-2.42227	-1.73262	-1.26394	-0.5564	-0.15643	0.112873	0.188627	0.601191	0.666613
	shear rat	1.588579	3.177157	5.295262	10.59052	52.95262	105.9052	158.8579	176.5087	317.7157	353.0174
	Vicosity	0.033665	0.027924	0.033392	0.026679	0.010826	0.008075	0.007047	0.006842	0.005742	0.005517
3ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.5	5	6.2	7.3	10.4	14.6	17	18.2	25.6	27.4
	Shear str	0.02705	0.0711	0.17682	0.27373	0.54684	0.91686	1.1283	1.23402	1.88596	2.04454
	LN(shear	-3.61007	-2.64367	-1.73262	-1.29561	-0.6036	-0.0868	0.120712	0.210277	0.634437	0.715173
	shear rat	1.566836	3.133673	5.222788	10.44558	52.22788	104.4558	156.6836	174.0929	313.3673	348.1858
	Vicosity	0.017264	0.022689	0.033855	0.026205	0.01047	0.008777	0.007201	0.007088	0.006018	0.005872
5ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.7	5.5	6.6	7	10.7	14.8	17.6	18	25.4	26.8
	Shear str	0.04467	0.11515	0.21206	0.2473	0.57327	0.93448	1.18116	1.2164	1.86834	1.99168
	LN(shear	-3.10845	-2.16152	-1.55089	-1.39715	-0.5564	-0.06777	0.166497	0.195896	0.62505	0.688979
	shear rat	1.586777	3.173554	5.289256	10.57851	52.89256	105.7851	158.6777	176.3085	317.3554	352.6171
	Vicosity	0.028151	0.036284	0.040093	0.023378	0.010838	0.008834	0.007444	0.006899	0.005887	0.005648
10ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.9	5.2	6	6.8	11.3	15	18	18.5	25.9	26.7
	Shear str	0.06229	0.08872	0.1592	0.22968	0.62613	0.9521	1.2164	1.26045	1.91239	1.98287
	LN(shear	-2.77595	-2.42227	-1.83759	-1.47107	-0.4682	-0.04909	0.195896	0.231469	0.648354	0.684545
	shear rat	1.587199	3.174399	5.290665	10.58133	52.90665	105.8133	158.7199	176.3555	317.4399	352.711
	Vicosity	0.039245	0.027949	0.030091	0.021706	0.011835	0.008998	0.007664	0.007147	0.006024	0.005622
30ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.6	5.3	6.3	7.1	11	14.9	18.4	18.7	26	27.8
	Shear str	0.03586	0.09753	0.18563	0.25611	0.5997	0.94329	1.25164	1.27807	1.9212	2.07978
	LN(shear	-3.32813	-2.3276	-1.684	-1.36215	-0.51133	-0.05838	0.224455	0.245351	0.65295	0.732262
	shear rat	1.576175	3.15235	5.253917	10.50783	52.53917	105.0783	157.6175	175.1306	315.235	350.2611
	Vicosity	0.022751	0.030939	0.035332	0.024373	0.011414	0.008977	0.007941	0.007298	0.006095	0.005938
50ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5	5.7	5.9	6.7	10.7	14.4	17.4	17.9	24.8	26.4
	Shear str	0.0711	0.13277	0.15039	0.22087	0.57327	0.89924	1.16354	1.20759	1.81548	1.95644
	LN(shear	-2.64367	-2.01914	-1.89452	-1.51018	-0.5564	-0.10621	0.151467	0.188627	0.59635	0.671126
	shear rat	1.598789	3.197578	5.329296	10.65859	53.29296	106.5859	159.8789	177.6432	319.7578	355.2864
	Vicosity	0.044471	0.041522	0.028219	0.020722	0.010757	0.008437	0.007278	0.006798	0.005678	0.005507
70ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.7	5.4	5.6	6.2	10.9	13.8	16.5	18	25.2	26.9
	Shear str	0.04467	0.10634	0.12396	0.17682	0.59089	0.84638	1.08425	1.2164	1.85072	2.00049
	LN(shear	-3.10845	-2.24111	-2.0878	-1.73262	-0.52613	-0.16679	0.080889	0.195896	0.615575	0.693392
	shear rat	1.580286	3.160572	5.26762	10.53524	52.6762	105.3524	158.0286	175.5873	316.0572	351.1746
	Vicosity	0.028267	0.033646	0.023532	0.016784	0.011217	0.008034	0.006861	0.006928	0.005856	0.005697

100ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5.2	5.9	5.7	6.5	10.8	14	17.2	18	24.6	27.2
	Shear stı	0.08872	0.15039	0.13277	0.20325	0.58208	0.864	1.14592	1.2164	1.79786	2.02692
	LN(shear	-2.42227	-1.89452	-2.01914	-1.59332	-0.54115	-0.14618	0.136208	0.195896	0.586597	0.706517
	shear rat	1.602401	3.204802	5.341336	10.68267	53.41336	106.8267	160.2401	178.0445	320.4802	356.0891
	Vicosity	0.055367	0.046926	0.024857	0.019026	0.010898	0.008088	0.007151	0.006832	0.00561	0.005692
150ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5.2	6	5.9	6.4	11.1	14.3	16.9	17.6	24.6	25.9
	Shear stı	0.08872	0.1592	0.15039	0.19444	0.60851	0.89043	1.11949	1.18116	1.79786	1.91239
	LN(shear	-2.42227	-1.83759	-1.89452	-1.63763	-0.49674	-0.11605	0.112873	0.166497	0.586597	0.648354
	shear rat	1.606505	3.21301	5.355016	10.71003	53.55016	107.1003	160.6505	178.5005	321.301	357.0011
	Vicosity	0.055225	0.049549	0.028084	0.018155	0.011363	0.008314	0.006968	0.006617	0.005596	0.005357

500ppm CMC +Alfonic 1412-3											
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reading	4.5	5.9	7.8	8.3	13.6	19.7	25	26.1	37.3	39.2
	Shear stress	0.02705	0.15039	0.31778	0.36183	0.82876	1.36617	1.8331	1.93001	2.91673	3.08412
	LN(shear stress	-3.61007	-1.89452	-1.1464	-1.01658	-0.18782	0.312011	0.606009	0.657525	1.070463	1.126266
	shear rate	1.564024	3.128047	5.213412	10.42682	52.13412	104.2682	156.4024	173.7804	312.8047	347.5608
	Vicosity	0.017295	0.048078	0.060954	0.034702	0.015897	0.013102	0.01172	0.011106	0.009324	0.008874
2ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	4.4	5.6	6.4	7.1	13.2	19.3	24	25.6	36	38.2
	Shear stress	0.01824	0.12396	0.19444	0.25611	0.79352	1.33093	1.745	1.88596	2.8022	2.99602
	LN(shear stress	-4.00414	-2.0878	-1.63763	-1.36215	-0.23128	0.285878	0.556755	0.634437	1.030405	1.097285
	shear rate	1.553908	3.107815	5.179692	10.35938	51.79692	103.5938	155.3908	172.6564	310.7815	345.3128
	Vicosity	0.011738	0.039887	0.037539	0.024723	0.01532	0.012848	0.01123	0.010923	0.009017	0.008676
3ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	4.2	5.6	6.2	6.8	13.1	19.8	25	26	37.4	38.7
	Shear stress	0.00062	0.12396	0.17682	0.22968	0.78471	1.37498	1.8331	1.9212	2.92554	3.04007
	LN(shear stress	-7.38579	-2.0878	-1.73262	-1.47107	-0.24244	0.318439	0.606009	0.65295	1.073479	1.111881
	shear rate	1.574172	3.148345	5.247241	10.49448	52.47241	104.9448	157.4172	174.908	314.8345	349.8161
	Vicosity	0.000394	0.039373	0.033698	0.021886	0.014955	0.013102	0.011645	0.010984	0.009292	0.00869
5ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	5.2	5.9	6.2	7.1	13.8	19.4	24.5	25.9	36.5	38.3
	Shear stress	0.08872	0.15039	0.17682	0.25611	0.84638	1.33974	1.78905	1.91239	2.84625	3.00483
	LN(shear stress	-2.42227	-1.89452	-1.73262	-1.36215	-0.16679	0.292476	0.581685	0.648354	1.046002	1.100221
	shear rate	1.582605	3.16521	5.27535	10.5507	52.7535	105.507	158.2605	175.845	316.521	351.69
	Vicosity	0.056059	0.047513	0.033518	0.024274	0.016044	0.012698	0.011304	0.010875	0.008992	0.008544
10ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	5	6	6.3	7.2	12.7	18.9	24.8	25	35.2	37
	Shear stress	0.0711	0.1592	0.18563	0.26492	0.74947	1.29569	1.81548	1.8331	2.73172	2.8903
	LN(shear stress	-2.64367	-1.83759	-1.684	-1.32833	-0.28839	0.259043	0.59635	0.606009	1.004931	1.06136
	shear rate	1.58145	3.1629	5.271501	10.543	52.71501	105.43	158.145	175.7167	316.29	351.4334
	Vicosity	0.044959	0.050334	0.035214	0.025128	0.014217	0.01229	0.01148	0.010432	0.008637	0.008224
30ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	4.9	6.1	6.4	7.6	13.2	18.7	23	23.9	33.8	35.8
	Shear stress	0.06229	0.16801	0.19444	0.30016	0.79352	1.27807	1.6569	1.73619	2.60838	2.78458
	LN(shear stress	-2.77595	-1.78373	-1.63763	-1.20344	-0.23128	0.245351	0.504948	0.551693	0.958729	1.024097
	shear rate	1.582977	3.165953	5.276589	10.55318	52.76589	105.5318	158.2977	175.8863	316.5953	351.7726
	Vicosity	0.03935	0.053068	0.03685	0.028443	0.015039	0.012111	0.010467	0.009871	0.008239	0.007916

50ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	5.1	5.8	6.3	7.7	12.9	18.3	23.1	24	34.7	35.5
	Shear stress	0.07991	0.14158	0.18563	0.30897	0.76709	1.24283	1.66571	1.745	2.68767	2.75815
	LN(shear stress	-2.52685	-1.95489	-1.684	-1.17451	-0.26515	0.217391	0.510251	0.556755	0.988675	1.01456
	shear rate	1.586224	3.172447	5.287412	10.57482	52.87412	105.7482	158.6224	176.2471	317.2447	352.4941
	Vicosity	0.050378	0.044628	0.035108	0.029218	0.014508	0.011753	0.010501	0.009901	0.008472	0.007825
70ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	4.7	5.3	6.4	8.2	13.5	20.8	23	25.1	35	37.9
	Shear stress	0.04467	0.09753	0.19444	0.35302	0.81995	1.46308	1.6569	1.84191	2.7141	2.96959
	LN(shear stress	-3.10845	-2.3276	-1.63763	-1.04123	-0.19851	0.380544	0.504948	0.610803	0.99846	1.088424
	shear rate	1.566786	3.133573	5.222621	10.44524	52.22621	104.4524	156.6786	174.0874	313.3573	348.1748
	Vicosity	0.028511	0.031124	0.03723	0.033797	0.0157	0.014007	0.010575	0.01058	0.008661	0.008529
100ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	4.9	5.4	6	6.8	13.9	19.3	23.3	25	35.6	37.8
	Shear stress	0.06229	0.10634	0.1592	0.22968	0.85519	1.33093	1.68333	1.8331	2.76696	2.96078
	LN(shear stress	-2.77595	-2.24111	-1.83759	-1.47107	-0.15643	0.285878	0.520774	0.606009	1.017749	1.085453
	shear rate	1.570921	3.141843	5.236405	10.47281	52.36405	104.7281	157.0921	174.5468	314.1843	349.0936
	Vicosity	0.039652	0.033846	0.030403	0.021931	0.016332	0.012708	0.010716	0.010502	0.008807	0.008481
150ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reading	4.6	5.9	5.7	7.3	12.9	18	22.3	23.8	33.7	35.9
	Shear stress	0.03586	0.15039	0.13277	0.27373	0.76709	1.2164	1.59523	1.72738	2.59957	2.79339
	LN(shear stress	-3.32813	-1.89452	-2.01914	-1.29561	-0.26515	0.195896	0.467018	0.546606	0.955346	1.027256
	shear rate	1.380711	2.761422	4.60237	9.204741	46.0237	92.04741	138.0711	153.4123	276.1422	306.8247
	Vicosity	0.025972	0.054461	0.028848	0.029738	0.016667	0.013215	0.011554	0.01126	0.009414	0.009104

700ppm CMC +Alfonic 1412-3											
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reac	4.8	5.6	6.2	8	16.3	24.7	30.8	33	47.2	49.3
	Shear str	0.05348	0.12396	0.17682	0.3354	1.06663	1.80667	2.34408	2.5379	3.78892	3.97393
	LN(shear	-2.92845	-2.0878	-1.73262	-1.09243	0.064504	0.591485	0.851893	0.931337	1.332081	1.379756
	shear rat	1.561085	3.12217	5.203617	10.40723	52.03617	104.0723	156.1085	173.4539	312.217	346.9078
	Vicosity	0.034258	0.039703	0.03398	0.032228	0.020498	0.01736	0.015016	0.014632	0.012136	0.011455
2ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5.2	6	6.2	8.3	17.9	24.8	31.6	33.1	47	50.5
	Shear str	0.08872	0.1592	0.17682	0.36183	1.20759	1.81548	2.41456	2.54671	3.7713	4.07965
	LN(shear	-2.42227	-1.83759	-1.73262	-1.01658	0.188627	0.59635	0.881517	0.934802	1.32742	1.406011
	shear rat	1.571301	3.142603	5.237671	10.47534	52.37671	104.7534	157.1301	174.589	314.2603	349.1781
	Vicosity	0.056463	0.050659	0.033759	0.034541	0.023056	0.017331	0.015367	0.014587	0.012001	0.011684
3ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5	5.9	6.6	8	16.9	24.6	31.5	32.8	47.1	50.3
	Shear str	0.0711	0.15039	0.21206	0.3354	1.11949	1.79786	2.40575	2.52028	3.78011	4.06203
	LN(shear	-2.64367	-1.89452	-1.55089	-1.09243	0.112873	0.586597	0.877862	0.92437	1.329753	1.401683
	shear rat	1.568983	3.137966	5.229943	10.45989	52.29943	104.5989	156.8983	174.3314	313.7966	348.6629
	Vicosity	0.045316	0.047926	0.040547	0.032065	0.021405	0.017188	0.015333	0.014457	0.012046	0.01165
5ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5.1	5.7	6.3	7.9	17.5	24.3	31	32.5	46.6	48.2
	Shear str	0.07991	0.13277	0.18563	0.32659	1.17235	1.77143	2.3617	2.49385	3.73606	3.87702
	LN(shear	-2.52685	-2.01914	-1.684	-1.11905	0.15901	0.571787	0.859382	0.913828	1.318032	1.355067
	shear rat	1.568394	3.136787	5.227979	10.45596	52.27979	104.5596	156.8394	174.266	313.6787	348.5319
	Vicosity	0.05095	0.042327	0.035507	0.031235	0.022425	0.016942	0.015058	0.014311	0.01191	0.011124

10ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.9	5.6	6.7	8.4	17.8	25.6	32.1	34	47.9	50.9
	Shear str	0.06229	0.12396	0.22087	0.37064	1.19878	1.88596	2.45861	2.626	3.85059	4.11489
	LN(shear	-2.77595	-2.0878	-1.51018	-0.99252	0.181304	0.634437	0.899596	0.965462	1.348226	1.414612
	shear rat	1.564313	3.128626	5.214376	10.42875	52.14376	104.2875	156.4313	173.8125	312.8626	347.6251
	Vicosity	0.039819	0.039621	0.042358	0.03554	0.02299	0.018084	0.015717	0.015108	0.012308	0.011837
30ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.7	5.4	6.8	8	18.3	25.6	32.2	33.9	48.8	51.2
	Shear str	0.04467	0.10634	0.22968	0.3354	1.24283	1.88596	2.46742	2.61719	3.92988	4.14132
	LN(shear	-3.10845	-2.24111	-1.47107	-1.09243	0.217391	0.634437	0.903173	0.962101	1.368609	1.421015
	shear rat	1.556828	3.113655	5.189426	10.37885	51.89426	103.7885	155.6828	172.9809	311.3655	345.9617
	Vicosity	0.028693	0.034153	0.044259	0.032316	0.023949	0.018171	0.015849	0.01513	0.012621	0.01197
50ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5.2	5.9	6.3	8	16.7	25.2	32.2	33.1	47.6	49.8
	Shear str	0.08872	0.15039	0.18563	0.3354	1.10187	1.85072	2.46742	2.54671	3.82416	4.01798
	LN(shear	-2.42227	-1.89452	-1.684	-1.09243	0.097009	0.615575	0.903173	0.934802	1.341339	1.390779
	shear rat	1.570941	3.141883	5.236471	10.47294	52.36471	104.7294	157.0941	174.549	314.1883	349.0981
	Vicosity	0.056476	0.047866	0.035449	0.032025	0.021042	0.017671	0.015707	0.01459	0.012172	0.01151
70ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.9	5.8	6.5	8.2	17.6	25.7	33	34	48.7	50.8
	Shear str	0.06229	0.14158	0.20325	0.35302	1.18116	1.89477	2.5379	2.626	3.92107	4.10608
	LN(shear	-2.77595	-1.95489	-1.59332	-1.04123	0.166497	0.639097	0.931337	0.965462	1.366365	1.412469
	shear rat	1.565958	3.131917	5.219861	10.43972	52.19861	104.3972	156.5958	173.9954	313.1917	347.9907
	Vicosity	0.039778	0.045206	0.038938	0.033815	0.022628	0.01815	0.016207	0.015092	0.01252	0.011799
100ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5	6.1	6.3	8.6	17	25.7	32.5	34	48.8	51.4
	Shear str	0.0711	0.16801	0.18563	0.38826	1.1283	1.89477	2.49385	2.626	3.92988	4.15894
	LN(shear	-2.64367	-1.78373	-1.684	-0.94608	0.120712	0.639097	0.913828	0.965462	1.368609	1.42526
	shear rat	1.568134	3.136268	5.227113	10.45423	52.27113	104.5423	156.8134	174.2371	313.6268	348.4742
	Vicosity	0.045341	0.05357	0.035513	0.037139	0.021586	0.018124	0.015903	0.015071	0.01253	0.011935
150ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.7	5.4	6.8	8	18.3	25.6	32.2	33.9	48.8	51.2
	Shear str	0.04467	0.10634	0.22968	0.3354	1.24283	1.88596	2.46742	2.61719	3.92988	4.14132
	LN(shear	-3.10845	-2.24111	-1.47107	-1.09243	0.217391	0.634437	0.903173	0.962101	1.368609	1.421015
	shear rat	1.556828	3.113655	5.189426	10.37885	51.89426	103.7885	155.6828	172.9809	311.3655	345.9617
	Vicosity	0.028693	0.034153	0.044259	0.032316	0.023949	0.018171	0.015849	0.01513	0.012621	0.01197

1000ppm CMC +Alfonic 1412-3											
Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reac	4.8	5.5	7.2	9.1	22.4	33.8	43.5	44	63.9	68.2
	Shear str	0.05348	0.11515	0.26492	0.43231	1.60404	2.60838	3.46295	3.507	5.26019	5.63902
	LN(shear	-2.92845	-2.16152	-1.32833	-0.83861	0.472525	0.958729	1.242121	1.254761	1.660167	1.72971
	shear rat	1.551884	3.103767	5.172945	10.34589	51.72945	103.4589	155.1884	172.4315	310.3767	344.863
	Vicosity	0.034461	0.0371	0.051213	0.041786	0.031008	0.025212	0.022314	0.020339	0.016948	0.016351
2ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.7	6.2	7.3	9.4	21.6	32.9	41.3	42.2	61	65
	Shear str	0.04467	0.17682	0.27373	0.45874	1.53356	2.52909	3.26913	3.34842	5.0047	5.3571
	LN(shear	-3.10845	-1.73262	-1.29561	-0.77927	0.427592	0.92786	1.184524	1.208489	1.610377	1.678423
	shear rat	1.554622	3.109245	5.182075	10.36415	51.82075	103.6415	155.4622	172.7358	310.9245	345.4716
	Vicosity	0.028734	0.056869	0.052822	0.044262	0.029594	0.024402	0.021028	0.019385	0.016096	0.015507

3ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5	5.9	7.4	9.7	21.4	31.2	40.2	41.5	60.9	64.1
	Shear str	0.0711	0.15039	0.28254	0.48517	1.51594	2.37932	3.17222	3.28675	4.99589	5.27781
	LN(shear	-2.64367	-1.89452	-1.26394	-0.72326	0.416036	0.866815	1.154432	1.189899	1.608616	1.663511
	shear rat	1.563984	3.127968	5.21328	10.42656	52.1328	104.2656	156.3984	173.776	312.7968	347.552
	Vicosity	0.045461	0.048079	0.054196	0.046532	0.029078	0.02282	0.020283	0.018914	0.015972	0.015186
5ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5.2	6.7	7.5	8.8	20.1	30.3	39.3	39.8	58	62.2
	Shear str	0.08872	0.22087	0.29135	0.40588	1.40141	2.30003	3.09293	3.13698	4.7404	5.11042
	LN(shear	-2.42227	-1.51018	-1.23323	-0.9017	0.337479	0.832922	1.129119	1.143261	1.556122	1.631282
	shear rat	1.570691	3.141383	5.235638	10.47128	52.35638	104.7128	157.0691	174.5213	314.1383	349.0426
	Vicosity	0.056485	0.07031	0.055647	0.038761	0.026767	0.021965	0.019692	0.017975	0.01509	0.014641
10ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.8	6.2	7.3	9.1	19.7	30	38.4	40.9	58.8	61.8
	Shear str	0.05348	0.17682	0.27373	0.43231	1.36617	2.2736	3.01364	3.23389	4.81088	5.07518
	LN(shear	-2.92845	-1.73262	-1.29561	-0.83861	0.312011	0.821364	1.103149	1.173686	1.57088	1.624362
	shear rat	1.561593	3.123186	5.205309	10.41062	52.05309	104.1062	156.1593	173.5103	312.3186	347.0206
	Vicosity	0.034247	0.056615	0.052587	0.041526	0.026246	0.021839	0.019299	0.018638	0.015404	0.014625
30ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.9	6	6.8	8.9	20	28.5	36.8	39	56	59.6
	Shear str	0.06229	0.1592	0.22968	0.41469	1.3926	2.14145	2.87268	3.0665	4.5642	4.88136
	LN(shear	-2.77595	-1.83759	-1.47107	-0.88022	0.331173	0.761483	1.055245	1.120537	1.518243	1.585424
	shear rat	1.561593	3.123186	5.205309	10.41062	52.05309	104.1062	156.1593	173.5103	312.3186	347.0206
	Vicosity	0.039889	0.050974	0.044124	0.039833	0.026753	0.02057	0.018396	0.017673	0.014614	0.014066
50ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5	6.2	6.7	8.5	20	30.8	39.3	41	58.8	62.4
	Shear str	0.0711	0.17682	0.22087	0.37945	1.3926	2.34408	3.09293	3.2427	4.81088	5.12804
	LN(shear	-2.64367	-1.73262	-1.51018	-0.96903	0.331173	0.851893	1.129119	1.176406	1.57088	1.634724
	shear rat	1.561742	3.123484	5.205807	10.41161	52.05807	104.1161	156.1742	173.5269	312.3484	347.0538
	Vicosity	0.045526	0.05661	0.042428	0.036445	0.026751	0.022514	0.019804	0.018687	0.015402	0.014776
70ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5.2	6	6.9	8.4	20	30	38	39.3	57.3	60.2
	Shear str	0.08872	0.1592	0.23849	0.37064	1.3926	2.2736	2.9784	3.09293	4.67873	4.93422
	LN(shear	-2.42227	-1.83759	-1.43343	-0.99252	0.331173	0.821364	1.091386	1.129119	1.543027	1.596195
	shear rat	1.565958	3.131917	5.219861	10.43972	52.19861	104.3972	156.5958	173.9954	313.1917	347.9907
	Vicosity	0.056655	0.050831	0.045689	0.035503	0.026679	0.021778	0.01902	0.017776	0.014939	0.014179
100ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	5	6.9	6.7	7.9	20.9	30.4	36.3	37.9	55.4	59.9
	Shear str	0.0711	0.23849	0.22087	0.32659	1.47189	2.30884	2.82863	2.96959	4.51134	4.90779
	LN(shear	-2.64367	-1.43343	-1.51018	-1.11905	0.386547	0.836745	1.039792	1.088424	1.506594	1.590824
	shear rat	1.565011	3.130022	5.216703	10.43341	52.16703	104.3341	156.5011	173.8901	313.0022	347.7802
	Vicosity	0.045431	0.076194	0.042339	0.031302	0.028215	0.022129	0.018074	0.017077	0.014413	0.014112
150ppm		0.9	1.8	3	6	30	60	90	100	180	200
	Dail Reac	4.7	5.7	7	8.3	19	29	37.2	39.5	57.1	60.1
	Shear str	0.04467	0.13277	0.2473	0.36183	1.3045	2.1855	2.90792	3.11055	4.66111	4.92541
	LN(shear	-3.10845	-2.01914	-1.39715	-1.01658	0.26582	0.781845	1.067438	1.1348	1.539254	1.594408
	shear rat	1.554116	3.108232	5.180387	10.36077	51.80387	103.6077	155.4116	172.6796	310.8232	345.3591
	Vicosity	0.028743	0.042716	0.047738	0.034923	0.025182	0.021094	0.018711	0.018013	0.014996	0.014262

Flow Data

500ppm CMC+30ppm Alfonic 1412-3 in 1 inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.099	1	2	1.243	0.158666	0.417017	824.7045	0.04977	2.074983	0.023873	0.000159
1.231	1	2	1.519	0.361154	0.949209	2500.517	0.08347	3.479959	0.007728	0.000362
1.342	1	2	1.96	0.531428	1.396735	4209.788	0.137316	5.724867	0.005871	0.000533
1.353	1	2	1.998	0.548302	1.441084	4391.046	0.141956	5.918305	0.005702	0.00055
1.473	1	2	2.56	0.732382	1.924895	6488.003	0.210576	8.779163	0.004741	0.000735
1.554	1	2	3.015	0.856636	2.251468	8014.842	0.266132	11.09534	0.004379	0.000859
1.629	1	2	3.463	0.971686	2.55385	9499.556	0.320832	13.37588	0.004103	0.000975
1.657	1	2	3.653	1.014638	2.666739	10070.17	0.344031	14.34307	0.004035	0.001018
1.838	1	2	4.861	1.292292	3.396488	13954.26	0.491528	20.49239	0.003554	0.001296
1.987	1	3	1.567	1.520858	3.997221	17381.63	0.689143	28.73118	0.003598	0.001525
2.265	1	3	1.754	1.94731	5.11805	24258.17	0.924407	38.53964	0.002944	0.001953
2.573	1	3	2.07	2.419782	6.359833	32515.2	1.321967	55.11437	0.002726	0.002427
2.943	1	3	2.521	2.987362	7.851585	43201.52	1.88937	78.77008	0.002557	0.002996
3.286	1	3	2.991	3.513524	9.234479	53766.87	2.480677	103.4224	0.002427	0.003524
3.603	1	3	3.449	3.999802	10.51255	64037.59	3.056887	127.4452	0.002307	0.004012
3.808	1	3	3.766	4.314272	11.33906	70918.92	3.455705	144.0724	0.002242	0.004327

500ppm CMC+30ppm Alfonic 1412-3 in 1.5 inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.148	2	2	1.114	0.233832	0.246065	545.5098	0.034019	0.669499	0.022124	0.000235
1.26	2	2	1.253	0.40564	0.426861	1146.667	0.050991	1.003505	0.011019	0.000407
1.343	2	2	1.443	0.532962	0.560844	1656.995	0.07419	1.46006	0.009287	0.000535
1.459	2	2	1.713	0.710906	0.748097	2443.726	0.107157	2.108848	0.007539	0.000713
1.617	2	2	2.173	0.953278	1.003148	3629.729	0.163323	3.21419	0.006391	0.000956
1.725	2	2	2.532	1.11895	1.177487	4505.311	0.207157	4.076838	0.005883	0.001122
1.842	2	2	2.981	1.298428	1.366355	5506.226	0.26198	5.155749	0.005525	0.001302
1.949	2	2	3.429	1.462566	1.53908	6465.073	0.316681	6.232256	0.005264	0.001467
2.123	2	2	4.265	1.729482	1.819959	8104.986	0.418757	8.241097	0.004978	0.001735
2.289	2	3	1.408	1.984126	2.087925	9754.4	0.489105	9.625546	0.004418	0.00199
2.498	2	3	1.526	2.304732	2.425303	11937.92	0.637561	12.54714	0.004268	0.002312
2.738	2	3	1.679	2.672892	2.812723	14578.94	0.83005	16.33532	0.004131	0.002681
2.937	2	3	1.808	2.978158	3.133959	16868.04	0.992345	19.52927	0.003978	0.002987
3.274	2	3	2.051	3.495116	3.677962	20932.01	1.298063	25.54578	0.003778	0.003506
3.697	2	3	2.409	4.143998	4.36079	26336.05	1.748463	34.40962	0.00362	0.004156
4.015	2	3	2.695	4.63181	4.874121	30600.61	2.10828	41.49078	0.003494	0.004646
4.294	2	3	2.965	5.059796	5.324497	34474.06	2.447967	48.1758	0.0034	0.005075
4.63	2	3	3.316	5.57522	5.866886	39292.32	2.88956	56.86632	0.003306	0.005592
4.659	2	3	3.342	5.619706	5.913699	39715.72	2.92227	57.51006	0.00329	0.005637

500ppm CMC +100ppm Alfonic 1412-3 in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in Vol
1.119	1	2	1.254	0.189346	0.497951	974.759	0.051113	2.130978	0.017206	0.0001899
1.228	1	2	1.489	0.356552	0.937677	2200.181	0.079807	3.327244	0.007576	0.0003576
1.375	1	2	2.117	0.58205	1.530702	4132.674	0.156486	6.524074	0.005574	0.0005838
1.459	1	2	2.56	0.710906	1.869573	5345.012	0.210576	8.779163	0.005028	0.000713
1.543	1	2	3.062	0.839762	2.208444	6622.239	0.27187	11.33459	0.004653	0.0008423
1.616	1	2	3.538	0.951744	2.50294	7779.168	0.32999	13.75767	0.004397	0.0009546
1.645	1	2	3.745	0.99623	2.619931	8249.976	0.355265	14.8114	0.00432	0.0009992
1.686	1	2	3.906	1.059124	2.785332	8925.895	0.374923	15.63097	0.004034	0.0010623
1.798	1	2	4.913	1.230932	3.237161	10830.06	0.497877	20.75709	0.003966	0.0012346
1.878	1	3	1.457	1.353652	3.559896	12238.27	0.550752	22.96149	0.003627	0.0013577
1.983	1	3	1.549	1.514722	3.983485	14142.46	0.666497	27.78704	0.003506	0.0015193
2.141	1	3	1.7	1.757094	4.620886	17117.58	0.85647	35.70725	0.003348	0.0017624
2.347	1	3	1.918	2.073098	5.451927	21175.36	1.130736	47.14171	0.003175	0.0020793
2.523	1	3	2.119	2.343082	6.161944	24786.79	1.383614	57.6845	0.003042	0.0023501
2.821	1	3	2.508	2.800214	7.36413	31173.44	1.873015	78.0882	0.002883	0.0028086
3.129	1	3	2.951	3.272686	8.606658	38096.42	2.430353	101.3243	0.002738	0.0032825
3.465	1	3	3.499	3.78811	9.962144	45981.98	3.119792	130.0678	0.002624	0.0037995
3.639	1	3	3.794	4.055026	10.66409	50190.89	3.490931	145.5411	0.002562	0.0040672
3.739	1	3	3.943	4.208426	11.06751	52646.3	3.678388	153.3564	0.002506	0.0042211
3.747	1	3	3.973	4.220698	11.09978	52843.85	3.716131	154.9299	0.002518	0.0042334

500ppm CMC +100ppm Alfonic 1412-3 in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in Vol
1.1	2	2	1.042	0.1602	0.168682	335.7697	0.025228	0.496489	0.034933	0.000161
1.226	2	2	1.21	0.353484	0.3722	929.2919	0.045741	0.900179	0.013009	0.000355
1.319	2	2	1.399	0.496146	0.522415	1437.297	0.068818	1.354331	0.009935	0.000498
1.498	2	2	1.861	0.770732	0.81154	2532.841	0.125228	2.46448	0.007492	0.000773
1.651	2	2	2.385	1.005434	1.058668	3565.427	0.189209	3.723609	0.006651	0.001008
1.754	2	2	2.787	1.163436	1.225036	4301.785	0.238293	4.689583	0.006256	0.001167
1.841	2	2	3.143	1.296894	1.36556	4946.673	0.28176	5.545022	0.005953	0.001301
1.972	2	2	3.739	1.497848	1.577154	5953.718	0.354532	6.977161	0.005616	0.001502
2.145	2	2	4.633	1.76323	1.856587	7343.64	0.463689	9.125371	0.0053	0.001769
2.314	2	3	1.459	2.022476	2.129559	8760.763	0.553268	10.88827	0.004807	0.002029
2.551	2	3	1.6	2.386034	2.512367	10836.51	0.73066	14.37933	0.004561	0.002393
2.851	2	3	1.807	2.846234	2.996933	13596.04	0.991087	19.50451	0.004348	0.002855
3.163	2	3	2.045	3.324842	3.500881	16604.97	1.290515	25.39723	0.004149	0.003335
3.443	2	3	2.281	3.754362	3.953143	19413.77	1.587426	31.24043	0.004002	0.003766
3.746	2	3	2.56	4.219164	4.442555	22558.64	1.938436	38.14828	0.00387	0.004232
4.108	2	3	2.92	4.774472	5.027264	26447.57	2.391352	47.06163	0.003728	0.004789
4.497	2	3	3.331	5.371198	5.655585	30773.34	2.908431	57.23771	0.003583	0.005387
4.752	2	3	3.627	5.762368	6.067466	33685.67	3.280829	64.56646	0.003511	0.00578

1.4 CMC- Aromox DMC

Bench-scale

500ppm CMC + Aromox											
Surface tension											
Concentration	5	10	20	30	50	70	100	120	150	200	300	500
	65.8	59.4	58.3	51.4	49.4	47.7	46	43.9	38	38	35.6	31.8
	66	60.2	58.2	53.2	48.2	46.6	46.2	44	37.4	37	35	32
Avg.	65.9	59.8	58.25	52.3	48.8	47.15	46.1	43.95	37.7	37.5	35.3	31.9
Conductivity												
Concentration	5	10	20	30	50	70	100	120	150	200	300	500
	0.56	0.549	0.554	0.554	0.553	0.55	0.543	0.535	0.551	0.554	0.561	0.567
	0.565	0.55	0.552	0.551	0.552	0.547	0.543	0.537	0.55	0.555	0.56	0.565
Avg.	0.563	0.5495	0.553	0.5525	0.5525	0.549	0.543	0.536	0.551	0.555	0.5605	0.566

Comcentration	RPM	0.9	1.8	3	6	30	60	90	100	180	200
5ppm	Dail Reading			6.8	7.9	15.2	22.2	28.9	29.9	40.8	43.1
	Shear stress			0.2297	0.3266	0.97	1.586	2.177	2.265	3.225	3.4277
	LN(shear stress)			-1.471	-1.119	-0.03	0.461	0.778	0.817	1.171	1.2319
	shear rate			5.274	10.548	52.74	105.5	158.2	175.8	316.4	351.6
	Viscosity			0.0435	0.031	0.018	0.015	0.014	0.013	0.01	0.0097
10ppm	Dail Reading			7.3	7.8	14.7	21.6	26.8	28.2	38.7	41
	Shear stress			0.2737	0.3178	0.926	1.534	1.992	2.115	3.04	3.2427
	LN(shear stress)			-1.296	-1.146	-0.08	0.428	0.689	0.749	1.112	1.1764
	shear rate			5.3053	10.611	53.05	106.1	159.2	176.8	318.3	353.68
	Viscosity			0.0516	0.0299	0.017	0.014	0.013	0.012	0.01	0.0092
20ppm	Dail Reading			7.2	8.2	14.9	22.7	27	28.9	41.8	42
	Shear stress			0.2649	0.353	0.943	1.63	2.009	2.177	3.313	3.3308
	LN(shear stress)			-1.328	-1.041	-0.06	0.489	0.698	0.778	1.198	1.2032
	shear rate			5.3024	10.605	53.02	106	159.1	176.7	318.1	353.49
	Viscosity			0.05	0.0333	0.018	0.015	0.013	0.012	0.01	0.0094
30ppm	Dail Reading			6.5	7.8	14.8	21.9	26.7	28.3	38.9	40.2
	Shear stress			0.2033	0.3178	0.934	1.56	1.983	2.124	3.058	3.1722
	LN(shear stress)			-1.593	-1.146	-0.07	0.445	0.685	0.753	1.118	1.1544
	shear rate			5.2716	10.543	52.72	105.4	158.1	175.7	316.3	351.44
	Vicosity			0.0386	0.0301	0.018	0.015	0.013	0.012	0.01	0.009

50ppm	Dail Reading	6.2	7.3	13.8	20.8	25.3	27.1	36.8	40
	Shear stress	0.1768	0.2737	0.846	1.463	1.86	2.018	2.873	3.1546
	LN(shear stress)	-1.733	-1.296	-0.17	0.381	0.62	0.702	1.055	1.1489
	shear rate	5.2508	10.502	52.51	105	157.5	175	315.1	350.06
	Vicosity	0.0337	0.0261	0.016	0.014	0.012	0.012	0.009	0.009
70ppm	Dail Reading	6.3	7.4	14.2	21.3	26.5	28	37.8	40.3
	Shear stress	0.1856	0.2825	0.882	1.507	1.965	2.097	2.961	3.181
	LN(shear stress)	-1.684	-1.264	-0.13	0.41	0.676	0.741	1.085	1.1572
	shear rate	5.2533	10.507	52.53	105.1	157.6	175.1	315.2	350.22
	Viscosity	0.0353	0.0269	0.017	0.014	0.012	0.012	0.009	0.0091
100ppm	Dail Reading	6.2	7.5	15.2	21	24.9	26.2	36	39.3
	Shear stress	0.1768	0.2914	0.97	1.481	1.824	1.939	2.802	3.0929
	LN(shear stress)	-1.733	-1.233	-0.03	0.393	0.601	0.662	1.03	1.1291
	shear rate	5.2618	10.524	52.62	105.2	157.9	175.4	315.7	350.79
	Viscosity	0.0336	0.0277	0.018	0.014	0.012	0.011	0.009	0.0088
120ppm	Dail Reading	6.1	7.3	15.8	21.8	25.9	27	37.1	39.7
	Shear stress	0.168	0.2737	1.023	1.551	1.912	2.009	2.899	3.1282
	LN(shear stress)	-1.784	-1.296	0.022	0.439	0.648	0.698	1.064	1.1404
	shear rate	5.2444	10.489	52.44	104.9	157.3	174.8	314.7	349.63
	Viscosity	0.032	0.0261	0.019	0.015	0.012	0.011	0.009	0.0089
150ppm	Dail Reading	7	8.3	14.7	20.1	25.3	26.9	36.8	38.8
	Shear stress	0.2473	0.3618	0.926	1.401	1.86	2	2.873	3.0489
	LN(shear stress)	-1.397	-1.017	-0.08	0.337	0.62	0.693	1.055	1.1148
	shear rate	5.3243	10.649	53.24	106.5	159.7	177.5	319.5	354.95
	Vicosity	0.0464	0.034	0.017	0.013	0.012	0.011	0.009	0.0086
200ppm	Dail Reading	6	7	14.8	20.3	26.9	27.9	39	40
	Shear stress	0.1592	0.2473	0.934	1.419	2	2.089	3.067	3.1546
	LN(shear stress)	-1.838	-1.397	-0.07	0.35	0.693	0.736	1.121	1.1489
	shear rate	5.2262	10.452	52.26	104.5	156.8	174.2	313.6	348.41
	Vicosity	0.0305	0.0237	0.018	0.014	0.013	0.012	0.01	0.0091
300ppm	Dail Reading	6.5	8	15.4	21.7	26.1	27	38.7	40.3
	Shear stress	0.2033	0.3354	0.987	1.542	1.93	2.009	3.04	3.181
	LN(shear stress)	-1.593	-1.092	-0.01	0.433	0.658	0.698	1.112	1.1572
	shear rate	5.2807	10.561	52.81	105.6	158.4	176	316.8	352.05
	Viscosity	0.0385	0.0318	0.019	0.015	0.012	0.011	0.01	0.009
500ppm	Dail Reading	6.8	7.8	14.8	20.9	25.1	28	38.3	40.9
	Shear stress	0.2297	0.3178	0.934	1.472	1.842	2.097	3.005	3.2339
	LN(shear stress)	-1.471	-1.146	-0.07	0.387	0.611	0.741	1.1	1.1737
	shear rate	5.2902	10.58	52.9	105.8	158.7	176.3	317.4	352.68
	Viscosity	0.0434	0.03	0.018	0.014	0.012	0.012	0.009	0.0092

Flow Data

500pm CMC +20ppm Aromox in 1inch pipe											
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.041	1	2	1.041	0.069694	0.183578	208.0487	0.025106	1.046703	0.062279	6.99037E-05
1.106	1	2	1.135	0.169404	0.446221	706.1361	0.036584	1.525209	0.01536	0.000169914
1.157	1	2	1.25	0.247638	0.652294	1190.599	0.050625	2.110616	0.009947	0.000248383
1.216	1	2	1.456	0.338144	0.890693	1827.694	0.075778	3.159258	0.007985	0.000339161
1.285	1	2	1.716	0.44399	1.169498	2658.478	0.107524	4.482786	0.006572	0.000445326
1.358	1	2	2.046	0.555972	1.464466	3622.686	0.147817	6.162649	0.005762	0.000557645
1.424	1	2	2.375	0.657216	1.731149	4560.338	0.187988	7.837421	0.005244	0.000659194
1.516	1	2	2.878	0.798344	2.102889	5959.855	0.249404	10.39794	0.004715	0.000800746
1.637	1	2	3.638	0.983958	2.591809	7946.005	0.3422	14.26671	0.004259	0.000986919
1.705	1	2	4.07	1.08827	2.866573	9127.637	0.394947	16.46581	0.004018	0.001091545
1.727	1	2	4.233	1.122018	2.955467	9519.347	0.414849	17.29556	0.00397	0.001125394
1.751	1	2	4.409	1.158834	3.052443	9951.744	0.436339	18.19149	0.003915	0.001162321
1.883	1	3	1.439	1.361322	3.585809	12420.22	0.528106	22.01736	0.003434	0.001365418
1.969	1	3	1.509	1.493246	3.933306	14105.86	0.616173	25.68898	0.00333	0.001497739
2.145	1	3	1.661	1.76323	4.644461	17730.01	0.807404	33.66163	0.003129	0.001768536
2.291	1	3	1.809	1.987194	5.234397	20900.72	0.993603	41.42448	0.003032	0.001993174
2.454	1	3	1.98	2.237236	5.893023	24602.59	1.208738	50.39372	0.00291	0.002243968
2.741	1	3	2.317	2.677494	7.052691	31500.98	1.632718	68.06993	0.002744	0.002685551
2.802	1	3	2.391	2.771068	7.299171	33025.59	1.725817	71.95136	0.002708	0.002779406
3.143	1	3	2.843	3.294162	8.677034	41896.49	2.294478	95.65952	0.002548	0.003304074
3.297	1	3	3.058	3.530398	9.299295	46085.36	2.56497	106.9366	0.00248	0.003541021
3.459	1	3	3.298	3.778906	9.953881	50606.98	2.866914	119.525	0.002419	0.003790277
3.64	1	3	3.579	4.05656	10.68524	55792.63	3.22044	134.264	0.002358	0.004068766
3.873	1	3	3.923	4.413982	11.62671	62666.4	3.653226	152.3073	0.002259	0.004427264

500pm CMC +20ppm Aromox in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.059	2	2	1.014	0.097306	0.102622	124.3621	0.021809	0.429207	0.081723	9.75988E-05
1.127	2	2	1.048	0.201618	0.212634	338.8508	0.025961	0.510907	0.022659	0.000202225
1.195	2	2	1.161	0.30593	0.322645	601.4147	0.039758	0.782436	0.015072	0.000306851
1.286	2	2	1.297	0.445524	0.469866	1008.761	0.056364	1.109233	0.010075	0.000446865
1.351	2	2	1.441	0.545234	0.575023	1331.898	0.073946	1.455254	0.008825	0.000546875
1.44	2	2	1.637	0.68176	0.719008	1811.341	0.097878	1.926226	0.007471	0.000683811
1.549	2	2	1.922	0.848966	0.89535	2449.44	0.132676	2.611058	0.006531	0.000851521
1.63	2	2	2.157	0.97322	1.026393	2955.876	0.16137	3.175744	0.006045	0.000976148
1.753	2	2	2.558	1.161902	1.225383	3772.014	0.210332	4.139314	0.005528	0.001165398
1.853	2	2	2.89	1.315302	1.387165	4473.771	0.250869	4.937083	0.005145	0.00131926
1.918	2	2	3.13	1.415012	1.492322	4946.949	0.280173	5.513784	0.004965	0.00141927
1.98	2	2	3.361	1.51012	1.592627	5410.14	0.308378	6.068858	0.004798	0.001514664
2.056	2	2	3.677	1.626704	1.71558	5993.024	0.346962	6.82818	0.004652	0.001631599
2.186	2	2	4.219	1.826124	1.925896	7026.614	0.41314	8.130562	0.004396	0.001831619
2.267	2	2	4.512	1.950378	2.056938	7692.74	0.448915	8.834618	0.004187	0.001956247
2.377	2	3	1.407	2.119118	2.234898	8623.101	0.487847	9.600787	0.003854	0.002125494
2.523	2	3	1.474	2.343082	2.471098	9901.414	0.572139	11.25966	0.003697	0.002350132
2.699	2	3	1.557	2.613066	2.755833	11504.4	0.676562	13.31468	0.003515	0.002620929
2.914	2	3	1.664	2.942876	3.103662	13548.46	0.811178	15.96393	0.003323	0.002951731
3.102	2	3	1.771	3.231268	3.407811	15408.24	0.945795	18.61318	0.003214	0.003240991
3.434	2	3	1.961	3.740556	3.944924	18845.58	1.184834	23.31745	0.003004	0.003751811
3.611	2	3	2.069	4.012074	4.231277	20753.05	1.320709	25.99145	0.002911	0.004024146
3.785	2	3	2.178	4.27899	4.512776	22676.14	1.457842	28.69022	0.002825	0.004291866
4.037	2	3	2.375	4.665558	4.920464	25541.77	1.705688	33.5678	0.00278	0.004679597
4.201	2	3	2.464	4.917134	5.185785	27455.74	1.817658	35.77138	0.002667	0.00493193
4.529	2	3	2.7	5.420286	5.716427	31394.08	2.11457	41.61458	0.002554	0.005436596
4.913	2	3	2.977	6.009342	6.337667	36182.17	2.463064	48.47291	0.00242	0.006027424

500pm CMC +100ppm Aromox in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.018	1	2	1.085	0.034412	0.090662	95.04628	0.030479	1.270685	0.310055	3.45155E-05
1.125	1	2	1.186	0.19855	0.523098	967.6336	0.042811	1.784825	0.013082	0.000199147
1.189	1	2	1.363	0.296726	0.781752	1647.138	0.064422	2.685842	0.008814	0.000297619
1.233	1	2	1.544	0.364222	0.959577	2160.628	0.086522	3.607221	0.007857	0.000365318
1.296	1	2	1.799	0.460864	1.214189	2950.54	0.117658	4.905297	0.006673	0.000462251
1.371	1	2	2.161	0.575914	1.517299	3963.188	0.161858	6.748056	0.005879	0.000577647
1.43	1	2	2.471	0.66642	1.755745	4808.101	0.199709	8.326109	0.005417	0.000668425
1.503	1	2	2.921	0.778402	2.050772	5905.888	0.254654	10.61683	0.005063	0.000780744
1.559	1	2	3.271	0.864306	2.277094	6783.893	0.297389	12.3985	0.004796	0.000866907
1.611	1	2	3.646	0.944074	2.48725	7624.988	0.343177	14.30744	0.004638	0.000946915
1.647	1	2	4.118	0.999298	2.632743	8221.052	0.400808	16.71015	0.004835	0.001002305
1.708	1	2	4.366	1.092872	2.879272	9255.437	0.431089	17.97259	0.004348	0.00109616
1.741	1	2	4.625	1.143494	3.012641	9827.269	0.462713	19.29103	0.004263	0.001146935
1.879	1	3	1.478	1.355186	3.570363	12305.46	0.577172	24.06298	0.003786	0.001359264
1.977	1	3	1.56	1.505518	3.966426	14144.49	0.680336	28.36401	0.003616	0.001510048
2.055	1	3	1.638	1.62517	4.281661	15651.69	0.778468	32.45524	0.003551	0.00163006
2.135	1	3	1.72	1.74789	4.604978	17235.34	0.881632	36.75628	0.003476	0.001753149
2.279	1	3	1.86	1.968786	5.186949	20176.69	1.057766	44.09952	0.003287	0.00197471
2.422	1	3	2.032	2.188148	5.764878	23205.6	1.274159	53.12121	0.003206	0.002194732
2.635	1	3	2.292	2.51489	6.62571	27900.91	1.601265	66.75864	0.00305	0.002522457
2.823	1	3	2.547	2.803282	7.385506	32213.8	1.922081	80.13382	0.002946	0.002811717
3.146	1	3	2.994	3.298764	8.690899	39960.25	2.484451	103.5797	0.00275	0.00330869
3.477	1	3	3.539	3.806518	10.02862	48300.33	3.170116	132.1659	0.002636	0.003817972
3.636	1	3	3.81	4.050424	10.67122	52439.9	3.511061	146.3803	0.002578	0.004062612
3.78	1	3	4.095	4.27132	11.25319	56259.44	3.86962	161.329	0.002555	0.004284173

500pm CMC +100ppm Aromox in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.063	2	2	1.019	0.103442	0.109116	165.5127	0.02242	0.441222	0.074324	0.000104
1.109	2	2	1.051	0.174006	0.18355	329.5184	0.026327	0.518115	0.030844	0.000175
1.2	2	2	1.167	0.3136	0.3308	718.7445	0.040491	0.796854	0.014605	0.000315
1.299	2	2	1.353	0.465466	0.490996	1212.429	0.063201	1.243797	0.010348	0.000467
1.434	2	2	1.648	0.672556	0.709444	1973.718	0.099221	1.952658	0.007781	0.000675
1.537	2	2	1.896	0.830558	0.876112	2609.868	0.129502	2.548582	0.006659	0.000833
1.647	2	2	2.22	0.999298	1.054107	3334.025	0.169062	3.327128	0.006005	0.001002
1.822	2	2	2.803	1.267748	1.337281	4568.654	0.240246	4.728029	0.005303	0.001272
1.92	2	2	3.136	1.41808	1.495858	5299.372	0.280906	5.528201	0.004955	0.001422
2.032	2	2	3.634	1.589888	1.677089	6165.694	0.341711	6.724855	0.004795	0.001595
2.089	2	2	3.874	1.677326	1.769323	6618.601	0.371015	7.301555	0.004678	0.001682
2.337	2	3	1.397	2.057758	2.17062	8675.744	0.475266	9.353193	0.003981	0.002064
2.48	2	3	1.477	2.27712	2.402014	9920.913	0.575914	11.33394	0.00394	0.002284
2.636	2	3	1.555	2.516424	2.654443	11324.28	0.674046	13.26517	0.003776	0.002524
2.922	2	3	1.712	2.955148	3.11723	14009.4	0.871567	17.15238	0.00354	0.002964
3.184	2	3	1.877	3.357056	3.541181	16586.01	1.079154	21.23766	0.003397	0.003367
3.372	2	3	1.982	3.645448	3.845391	18498.26	1.211254	23.83739	0.003233	0.003656
3.504	2	3	2.081	3.847936	4.058985	19870.75	1.335806	26.28856	0.0032	0.00386
3.71	2	3	2.225	4.16394	4.392321	22059.55	1.516973	29.85391	0.003104	0.004176
3.793	2	3	2.289	4.291262	4.526626	22957.01	1.597491	31.4385	0.003077	0.004304
3.969	2	3	2.419	4.561246	4.811418	24888.53	1.761044	34.65721	0.003003	0.004575
4.213	2	3	2.611	4.935542	5.206243	27627.91	2.002599	39.411	0.002916	0.00495
4.49	2	3	2.787	5.36046	5.654467	30820.25	2.224025	43.76864	0.002746	0.005377
4.949	2	3	3.212	6.064566	6.397191	36291.05	2.758717	54.29135	0.002661	0.006083

500pm CMC +300ppm Aromox in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.058	1	2	1.031	0.095772	0.252118	345.5063	0.023885	0.995798	0.031395	9.60602E-05
1.11	1	2	1.147	0.17554	0.462106	781.8782	0.038049	1.586295	0.014887	0.000176068
1.149	1	2	1.302	0.235366	0.619596	1160.962	0.056974	2.375322	0.012399	0.000236074
1.24	1	2	1.54	0.37496	0.987075	2174.798	0.086034	3.586859	0.007378	0.000376088
1.302	1	2	1.805	0.470068	1.237445	2949.51	0.118391	4.93584	0.00646	0.000471482
1.41	1	2	2.347	0.63574	1.673573	4430.829	0.184569	7.694888	0.005506	0.000637653
1.513	1	2	2.985	0.793742	2.08951	5976.162	0.262469	10.94262	0.005023	0.00079613
1.596	1	2	3.541	0.921064	2.424683	7303.159	0.330356	13.77294	0.004695	0.000923836
1.694	1	2	4.306	1.071396	2.820429	8953.94	0.423763	17.66716	0.004451	0.00107462
1.735	1	2	4.626	1.13429	2.985996	9669.57	0.462835	19.29612	0.004337	0.001137703
1.849	1	3	1.457	1.309166	3.446354	11731.18	0.550752	22.96149	0.003874	0.001313105
1.922	1	3	1.53	1.421148	3.741144	13103.49	0.642593	26.79046	0.003836	0.001425424
2.013	1	3	1.605	1.560742	4.108623	14867.42	0.736951	30.72434	0.003647	0.001565438
2.14	1	3	1.738	1.75556	4.621478	17421.78	0.904278	37.70041	0.003537	0.001760843
2.381	1	3	2.008	2.125254	5.59469	22540.4	1.243965	51.86237	0.00332	0.002131649
2.548	1	3	2.21	2.381432	6.269073	26277.54	1.498101	62.4576	0.003185	0.002388598
2.799	1	3	2.562	2.766466	7.282668	32159.98	1.940952	80.9206	0.003058	0.00277479
3.08	1	3	2.991	3.19752	8.417409	39091.5	2.480677	103.4224	0.002925	0.003207141
3.522	1	3	3.751	3.875548	10.2023	50659.25	3.436833	143.2856	0.002759	0.00388721
3.753	1	3	4.164	4.229902	11.13513	57000.04	3.956428	164.9482	0.002666	0.00424263

500pm CMC +300ppm Aromox in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.044	2	2	1.001	0.074296	0.078308	96.29619	0.020222	0.397969	0.130058	7.45196E-05
1.089	2	2	1.021	0.143326	0.151066	233.4776	0.022664	0.446028	0.039168	0.000143757
1.178	2	2	1.143	0.279852	0.294964	575.3732	0.03756	0.739184	0.017026	0.000280694
1.314	2	2	1.361	0.488476	0.514855	1219.064	0.064178	1.26302	0.009549	0.000489946
1.418	2	2	1.577	0.648012	0.683006	1784.299	0.090552	1.782051	0.007655	0.000649962
1.518	2	2	1.839	0.801412	0.84469	2375.976	0.122542	2.411615	0.006774	0.000803823
1.684	2	2	2.328	1.056056	1.113085	3446.374	0.182249	3.586643	0.005801	0.001059234
1.908	2	2	3.164	1.399672	1.475257	5038.063	0.284324	5.595483	0.005152	0.001403884
2.071	2	2	3.844	1.649714	1.738801	6287.528	0.367352	7.229468	0.004792	0.001654678
2.184	2	2	4.341	1.823056	1.921504	7193.945	0.428036	8.423718	0.004572	0.001828542
2.341	2	3	1.412	2.063894	2.175348	8503.582	0.494137	9.724583	0.004118	0.002070104
2.485	2	3	1.491	2.28479	2.408173	9752.674	0.593527	11.68057	0.004036	0.002291665
2.677	2	3	1.584	2.579318	2.718606	11484.24	0.71053	13.98319	0.003792	0.002587079
2.813	2	3	1.673	2.787942	2.938496	12753.6	0.822501	16.18676	0.003757	0.002796331
3.09	2	3	1.825	3.21286	3.38636	15440.96	1.013733	19.95018	0.003486	0.003222528
3.314	2	3	1.98	3.556476	3.748532	17707.39	1.208738	23.78787	0.003393	0.003567178
3.606	2	3	2.174	4.004404	4.220649	20777.61	1.452809	28.59118	0.003216	0.004016453
3.89	2	3	2.377	4.44006	4.679831	23880.87	1.708204	33.61732	0.003076	0.00445342
4.348	2	3	2.749	5.142632	5.420343	29109.96	2.176217	42.82779	0.002921	0.005158106
4.819	2	3	3.149	5.865146	6.181874	34753.44	2.679457	52.73151	0.002765	0.005882794
4.979	2	3	3.289	6.110586	6.440568	36727.88	2.855591	56.19782	0.002715	0.006128973

500pm CMC +500ppm Aromox in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.047	1	2	1.041	0.078898	0.207781	266.786	0.025106	1.046703	0.048606	7.91354E-05
1.14	1	2	1.226	0.22156	0.583486	1086.479	0.047695	1.988444	0.011709	0.000222227
1.228	1	2	1.51	0.356552	0.938993	2075.106	0.082371	3.434145	0.007809	0.000357625
1.294	1	2	1.805	0.457796	1.205622	2915.192	0.118391	4.93584	0.006808	0.000459174
1.348	1	2	2.071	0.540632	1.423774	3655.103	0.150869	6.289911	0.006221	0.000542259
1.414	1	2	2.415	0.641876	1.690404	4616.223	0.192872	8.041041	0.005642	0.000643807
1.46	1	2	2.725	0.71244	1.876236	5319.747	0.230723	9.619094	0.005478	0.000714584
1.5	1	2	2.978	0.7738	2.03783	5952.348	0.261614	10.90699	0.005266	0.000776128
1.544	1	2	3.25	0.841296	2.215583	6669.353	0.294825	12.2916	0.00502	0.000843827
1.583	1	2	3.541	0.901122	2.373137	7322.493	0.330356	13.77294	0.004903	0.000903834
1.617	1	2	3.788	0.953278	2.510492	7904.818	0.360515	15.03029	0.004781	0.000956146
1.651	1	2	4.067	1.005434	2.647847	8498.732	0.394581	16.45054	0.004704	0.001008459
1.687	1	2	4.343	1.060658	2.793281	9139.781	0.42828	17.85551	0.004588	0.00106385
1.823	1	3	1.449	1.269282	3.3427	11667.89	0.540687	22.54188	0.004045	0.001273101
2.003	1	3	1.625	1.545402	4.069872	15249.29	0.762113	31.77337	0.003846	0.001550052
2.175	1	3	1.8	1.80925	4.764725	18895.19	0.98228	40.95242	0.003616	0.001814694
2.378	1	3	2.048	2.120652	5.584814	23450.48	1.294289	53.96043	0.003468	0.002127033
2.606	1	3	2.346	2.470404	6.505898	28861.42	1.669203	69.59103	0.003296	0.002477838
2.815	1	3	2.639	2.79101	7.350226	34071.31	2.037826	84.95937	0.003153	0.002799408
3.013	1	3	2.966	3.094742	8.150115	39210.51	2.449225	102.1111	0.003082	0.003104054
3.491	1	3	3.773	3.827994	10.08116	52359.34	3.464511	144.4396	0.002849	0.003839513
3.586	1	3	3.948	3.973724	10.46495	55088.65	3.684679	153.6186	0.002812	0.003985681
3.689	1	3	4.17	4.131726	10.88105	58088.76	3.963977	165.2629	0.002798	0.004144158

500pm CMC +500ppm Aromox in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.079	2	2	1.028	0.127986	0.134952	198.8243	0.023519	0.462848	0.050951	0.000128
1.091	2	2	1.04	0.146394	0.154361	238.6932	0.024984	0.491683	0.04137	0.000147
1.17	2	2	1.28	0.26758	0.282143	542.0825	0.054288	1.068384	0.026907	0.000268
1.205	2	2	1.172	0.32127	0.338755	695.1394	0.041101	0.808869	0.014131	0.000322
1.253	2	2	1	0.394902	0.416394	920.352	0.052212	1.027534	0.011881	0.000396
1.347	2	2	1.446	0.539098	0.568438	1405.389	0.074557	1.467268	0.009104	0.000541
1.42	2	2	1.599	0.65108	0.686515	1816.65	0.093238	1.834915	0.007805	0.000653
1.486	2	2	1.772	0.752324	0.793269	2211.257	0.114361	2.25062	0.00717	0.000755
1.544	2	2	1.935	0.841296	0.887083	2574.298	0.134264	2.642296	0.006732	0.000844
1.597	2	2	2.08	0.922598	0.97281	2918.404	0.151968	2.990719	0.006336	0.000925
1.656	2	2	2.272	1.013104	1.068241	3314.499	0.175411	3.452079	0.006065	0.001016
1.72	2	2	2.504	1.11128	1.171761	3758.793	0.203738	4.009556	0.005855	0.001115
1.8	2	2	2.776	1.234	1.30116	4334.281	0.23695	4.66315	0.005522	0.001238
1.936	2	2	3.323	1.442624	1.521138	5360.148	0.303738	5.977547	0.005179	0.001447
2.006	2	2	3.614	1.550004	1.634362	5909.913	0.339269	6.676796	0.005011	0.001555
2.101	2	2	4.061	1.695734	1.788023	6678.132	0.393848	7.750901	0.00486	0.001701
2.265	2	2	4.846	1.94731	2.053291	8060.467	0.489697	9.637192	0.004583	0.001953
2.474	2	3	1.494	2.267916	2.391346	9917.019	0.597301	11.75485	0.004121	0.002275
2.677	2	3	1.609	2.579318	2.719696	11813.41	0.741983	14.60217	0.003958	0.002587
2.933	2	3	1.76	2.972022	3.133772	14324.49	0.931956	18.34082	0.003744	0.002981
3.294	2	3	1.984	3.525796	3.717685	18071.67	1.21377	23.88691	0.003465	0.003536
3.518	2	3	2.158	3.869412	4.080002	20508.11	1.43268	28.19503	0.003396	0.003881
3.79	2	3	2.351	4.28666	4.519959	23572.76	1.675493	32.97358	0.003236	0.0043
4.164	2	3	2.641	4.860376	5.124899	27964.01	2.040342	40.15378	0.003065	0.004875

1.5 CMC- Stepanol WA-100

Bench-scale

500ppm CMC + Stepanol										
Surface tension										
Concentration	20	40	60	80	100	200	300	500	700	1000
	63.4	63	61.7	58	55.8	49.5	41.2	36.2	34.5	33.1
	63.8	62.9	61.5	57.4	55.6	48.7	40.8	36.7	34.6	34
Avg.	63.6	62.95	61.6	57.7	55.7	49.1	41	36.45	34.55	33.55
Conductivity										
Concentration	20	40	60	80	100	200	300	500	700	1000
	0.594	0.612	0.643	0.658	0.669	0.786	0.944	1.157	1.41	1.715
	0.596	0.607	0.641	0.656	0.661	0.786	0.927	1.16	1.407	1.718
Avg.	0.595	0.6095	0.642	0.657	0.665	0.786	0.936	1.1585	1.4085	1.7165

Viscosity							
Concentration	RPM	30	60	90	100	180	200
20ppm	Dail Reading	14.9	19.6	24.8	26.5	36.4	39.5
	Shear stress	0.943	1.3574	1.815	1.965	2.8374	3.11055
	LN(shear stress)	-0.06	0.3055	0.596	0.676	1.0429	1.1348
	shear rate	52.94	105.89	158.8	176.5	317.66	352.959
	Vicosity	0.018	0.0128	0.011	0.011	0.0089	0.00881
40ppm	Dail Reading	13	18.5	23.5	24.9	34	36.6
	Shear stress	0.776	1.2605	1.701	1.824	2.626	2.85506
	LN(shear stress)	-0.25	0.2315	0.531	0.601	0.9655	1.04909
	shear rate	52.57	105.15	157.7	175.2	315.44	350.493
	Vicosity	0.015	0.012	0.011	0.01	0.0083	0.00815
60ppm	Dail Reading	14.1	18.2	22.3	23.6	33.2	35.3
	Shear stress	0.873	1.234	1.595	1.71	2.5555	2.74053
	LN(shear stress)	-0.14	0.2103	0.467	0.536	0.9383	1.00815
	shear rate	53.12	106.24	159.4	177.1	318.71	354.124
	Vicosity	0.016	0.0116	0.01	0.01	0.008	0.00774
80ppm	Dail Reading	12.8	18.1	22.3	23.7	32.9	35.1
	Shear stress	0.758	1.2252	1.595	1.719	2.5291	2.72291
	LN(shear stress)	-0.28	0.2031	0.467	0.541	0.9279	1.0017
	shear rate	52.66	105.33	158	175.5	315.99	351.099
	Vicosity	0.014	0.0116	0.01	0.01	0.008	0.00776
100ppm	Dail Reading	12.3	18	21.2	22.1	32.3	34.2
	Shear stress	0.714	1.2164	1.498	1.578	2.4762	2.64362
	LN(shear stress)	-0.34	0.1959	0.404	0.456	0.9067	0.97215
	shear rate	52.57	105.14	157.7	175.2	315.43	350.477
	Vicosity	0.014	0.0116	0.01	0.009	0.0079	0.00754
200ppm	Dail Reading	12	15.2	20.1	20.8	29.7	31
	Shear stress	0.688	0.9697	1.401	1.463	2.2472	2.3617
	LN(shear stress)	-0.37	-0.031	0.337	0.381	0.8097	0.85938
	shear rate	52.62	105.23	157.9	175.4	315.7	350.778
	Vicosity	0.013	0.0092	0.009	0.008	0.0071	0.00673

300ppm	Dail Reading	10.3	13.7	17.2	18.7	26.9	28.9
	Shear stress	0.538	0.8376	1.146	1.278	2.0005	2.17669
	LN(shear stress)	-0.62	-0.177	0.136	0.245	0.6934	0.77781
	shear rate	52.16	104.31	156.5	173.9	312.93	347.7
	Vicosity	0.01	0.008	0.007	0.007	0.0064	0.00626
500ppm	Dail Reading	9	12.1	14.8	15.9	23.5	24.9
	Shear stress	0.424	0.6966	0.934	1.031	1.701	1.82429
	LN(shear stress)	-0.86	-0.362	-0.07	0.031	0.5312	0.60119
	shear rate	51.98	103.95	155.9	173.3	311.85	346.505
	Vicosity	0.008	0.0067	0.006	0.006	0.0055	0.00526
700ppm	Dail Reading	8.4	11.7	15	15.6	23	24.3
	Shear stress	0.371	0.6614	0.952	1.005	1.6569	1.77143
	LN(shear stress)	-0.99	-0.413	-0.05	0.005	0.5049	0.57179
	shear rate	51.72	103.44	155.2	172.4	310.33	344.81
	Viscosity	0.007	0.0064	0.006	0.006	0.0053	0.00514
1000ppm	Dail Reading	8	10.8	13.8	15	21.6	23.1
	Shear stress	0.335	0.5821	0.846	0.952	1.5336	1.66571
	LN(shear stress)	-1.09	-0.541	-0.17	-0.05	0.4276	0.51025
	shear rate	51.61	103.21	154.8	172	309.63	344.037
	Viscosity	0.006	0.0056	0.005	0.006	0.005	0.00484

Flow Data

500ppm CMC with 100ppm Stepanol in 1inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.104	1	2	1.185	0.166336	0.438008	925.0023	0.042689	1.779734	0.018596	0.000167
1.204	1	2	1.434	0.319736	0.841952	2189.618	0.073091	3.047267	0.008617	0.000321
1.277	1	2	1.696	0.431718	1.136831	3253.308	0.105082	4.380976	0.006795	0.000433
1.36	1	2	2.058	0.55904	1.472104	4574.341	0.149282	6.223735	0.005757	0.000561
1.464	1	2	2.555	0.718576	1.892206	6369.352	0.209966	8.75371	0.004901	0.000721
1.563	1	2	3.099	0.870442	2.292111	8201.462	0.276388	11.52294	0.004397	0.000873
1.637	1	2	3.535	0.983958	2.591029	9640.27	0.329624	13.74239	0.004103	0.000987
1.676	1	2	3.796	1.043784	2.748567	10420.54	0.361492	15.07101	0.003999	0.001047
1.81	1	2	4.727	1.24934	3.289852	13207.89	0.475167	19.81026	0.003669	0.001253
1.94	1	3	1.47	1.44876	3.814979	16056.11	0.567107	23.64336	0.003257	0.001453
2.045	1	3	1.535	1.60983	4.23912	18450.6	0.648884	27.05272	0.003018	0.001615
2.189	1	3	1.684	1.830726	4.8208	21859.76	0.83634	34.86802	0.003008	0.001836
2.43	1	3	1.911	2.20042	5.794305	27859.81	1.121929	46.77455	0.002793	0.002207
2.567	1	3	2.062	2.410578	6.347708	31420.66	1.311902	54.69476	0.002721	0.002418
2.751	1	3	2.281	2.692834	7.090965	36360.07	1.587426	66.18167	0.002639	0.002701
2.95	1	3	2.507	2.9981	7.894813	41890.89	1.871757	78.03575	0.00251	0.003007
3.177	1	3	2.816	3.346318	8.811766	48422.21	2.26051	94.24332	0.002433	0.003356
3.472	1	3	3.229	3.798848	10.0034	57237.33	2.780105	115.9059	0.002322	0.00381
3.64	1	3	3.489	4.05656	10.68203	62411.89	3.107211	129.5433	0.002276	0.004069
3.785	1	3	3.675	4.27899	11.26775	66963.31	3.341218	139.2993	0.002199	0.004292
3.857	1	3	3.847	4.389438	11.55858	69251.74	3.557611	148.321	0.002225	0.004403

500ppm CMC with 100ppm Stepanol in 1.5inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.052	2	2	1.025	0.086568	0.09127	159.7391	0.023153	0.455639	0.109646	8.68285E-05
1.119	2	2	1.083	0.189346	0.199631	448.334	0.030234	0.595009	0.029929	0.000189916
1.18	2	2	1.159	0.28292	0.298288	761.3343	0.039514	0.777631	0.01752	0.000283771
1.267	2	2	1.287	0.416378	0.438995	1267.268	0.055143	1.085204	0.011288	0.000417631
1.386	2	2	1.543	0.598924	0.631457	2046.699	0.0864	1.700351	0.008548	0.000600726
1.487	2	2	1.762	0.753858	0.794807	2772.08	0.11314	2.226591	0.007066	0.000756126
1.597	2	2	2.061	0.922598	0.972712	3618.072	0.149648	2.945063	0.00624	0.000925374
1.73	2	2	2.46	1.12662	1.187816	4708.532	0.198366	3.903828	0.005547	0.00113001
1.854	2	2	2.87	1.316836	1.388365	5783.973	0.248427	4.889025	0.005084	0.001320798
1.937	2	2	3.151	1.444158	1.522603	6532.504	0.282737	5.564245	0.004811	0.001448504
1.982	2	2	3.313	1.513188	1.595382	6947.339	0.302517	5.953518	0.004689	0.001517741
2.13	2	2	3.906	1.74022	1.834746	8353.575	0.374923	7.378449	0.004394	0.001745456
2.278	2	2	4.476	1.967252	2.07411	9819.639	0.44452	8.748112	0.004076	0.001973172
2.34	2	2	4.763	2.06236	2.174385	10450.4	0.479562	9.43775	0.004002	0.002068566
2.539	2	3	1.459	2.367626	2.496232	12536.64	0.553268	10.88827	0.003503	0.00237475
2.79	2	3	1.578	2.75266	2.902181	15292.18	0.702982	13.83463	0.003293	0.002760943
2.976	2	3	1.678	3.037984	3.203003	17416.02	0.828792	16.31056	0.003187	0.003047125
3.131	2	3	1.75	3.275754	3.453688	19235.4	0.919375	18.09323	0.003041	0.003285611
3.339	2	3	1.863	3.594826	3.790092	21743.46	1.06154	20.89103	0.002915	0.003605643
3.542	2	3	1.984	3.906228	4.118409	24260.7	1.21377	23.88691	0.002823	0.003917982
3.777	2	3	2.118	4.266718	4.49848	27255.47	1.382356	27.20466	0.002695	0.004279557
4.022	2	3	2.282	4.642548	4.894725	30464.69	1.588684	31.26519	0.002616	0.004656518
4.411	2	3	2.544	5.239274	5.523864	35730.79	1.918306	37.75213	0.00248	0.005255039
4.777	2	3	2.787	5.800718	6.115805	40863.8	2.224025	43.76864	0.002346	0.005818173

500ppm CMC with 300ppm Stepanol in 1inch										
FR signa	Measure	Channel	PD signa	Flow rat	Velocity	Re	PD	S Stress	f	Fr in vol
1.064	1	2	1.094	0.104976	0.276264	677.5846	0.031577	1.316499	0.034557	0.000105
1.148	1	2	1.242	0.233832	0.615373	1849.937	0.049648	2.069892	0.010951	0.000235
1.226	1	2	1.483	0.353484	0.93026	3106.169	0.079074	3.296701	0.007632	0.000355
1.268	1	2	1.652	0.417912	1.099815	3831.926	0.099709	4.156995	0.006885	0.000419
1.305	1	2	1.769	0.47467	1.249184	4495.495	0.113995	4.752582	0.006102	0.000476
1.409	1	2	2.279	0.634206	1.669033	6465.344	0.176266	7.348734	0.005285	0.000636
1.491	1	2	2.747	0.759994	2.000068	8112.199	0.233409	9.731085	0.004873	0.000762
1.538	1	2	3.019	0.832092	2.189808	9088.693	0.26662	11.1157	0.004644	0.000835
1.628	1	2	3.588	0.970152	2.553139	11018.19	0.336095	14.01219	0.004307	0.000973
1.653	1	2	3.764	1.008502	2.654064	11567.13	0.357584	14.90812	0.00424	0.001012
1.765	1	2	4.463	1.18031	3.106209	14089.8	0.442932	18.46637	0.003834	0.001184
1.838	1	3	1.414	1.292292	3.400911	15785.99	0.496653	20.70607	0.003587	0.001296
1.95	1	3	1.501	1.4641	3.853057	18461.07	0.606108	25.26936	0.00341	0.001469
2.114	1	3	1.643	1.715676	4.515126	22522.67	0.784758	32.7175	0.003215	0.001721
2.318	1	3	1.844	2.028612	5.338677	27788.99	1.037636	43.26029	0.003041	0.002035
2.452	1	3	1.992	2.234168	5.879636	31364.67	1.223835	51.02314	0.002957	0.002241
2.757	1	3	2.353	2.702038	7.110925	39810.61	1.678009	69.95819	0.002772	0.00271
3.006	1	3	2.681	3.084004	8.116141	46990.88	2.090666	87.16234	0.002651	0.003093
3.019	1	3	2.7	3.103946	8.168622	47372.26	2.11457	88.15893	0.002647	0.003113
3.259	1	3	3.031	3.472106	9.137505	54522.05	2.531001	105.5204	0.002532	0.003483
3.569	1	3	3.499	3.947646	10.38898	64044.57	3.119792	130.0678	0.002414	0.00396
3.704	1	3	3.735	4.154736	10.93397	68285.72	3.416704	142.4464	0.002387	0.004167
3.776	1	3	3.84	4.265184	11.22464	70569.9	3.548804	147.9538	0.002353	0.004278

500ppm CMC with 300ppm Stepanol in 1.5inch										
FR signa	Measure	Channel	PD signa	Flow rat	Velocity	Re	PD	S Stress	f	Fr in vol
1.054	2	2	1.018	0.089636	0.094448	248.1102	0.022298	0.438819	0.098553	8.99057E-05
1.193	2	2	1.141	0.302862	0.319121	1142.261	0.037316	0.734378	0.014447	0.000303773
1.307	2	2	1.349	0.477738	0.503385	2023.058	0.062713	1.234185	0.009758	0.000479176
1.458	2	2	1.684	0.709372	0.747455	3321.372	0.103616	2.039163	0.007312	0.000711507
1.643	2	2	2.185	0.993162	1.04648	5065.232	0.164789	3.243025	0.005933	0.00099615
1.826	2	2	2.815	1.273884	1.342272	6921.175	0.241712	4.756864	0.005289	0.001277717
1.956	2	2	3.273	1.473304	1.552398	8305.999	0.297633	5.857401	0.004869	0.001477737
2.099	2	2	3.835	1.692666	1.783537	9885.25	0.366254	7.207841	0.00454	0.001697759
2.229	2	2	4.372	1.892086	1.993663	11367.06	0.431821	8.498209	0.004283	0.001897779
2.362	2	2	4.995	2.096108	2.208637	12924.72	0.50789	9.995227	0.004105	0.002102415
2.529	2	3	1.483	2.352286	2.478568	14935.58	0.583462	11.48249	0.003745	0.002359364
2.75	2	3	1.589	2.6913	2.835782	17682.84	0.716821	14.10698	0.003514	0.002699398
3.004	2	3	1.718	3.080936	3.246336	20950.45	0.879116	17.30093	0.003289	0.003090207
3.23	2	3	1.853	3.42762	3.611632	23948.08	1.048959	20.64344	0.003171	0.003437934
3.527	2	3	2.023	3.883218	4.091688	28005.4	1.262836	24.85252	0.002974	0.003894903
3.779	2	3	2.191	4.269786	4.499009	31544.87	1.474197	29.01209	0.002872	0.004282634
4.036	2	3	2.359	4.664024	4.914412	35239.46	1.685558	33.17165	0.002752	0.004678058
4.357	2	3	2.577	5.156438	5.433261	39966.33	1.959824	38.56918	0.002618	0.005171954
4.713	2	3	2.844	5.702542	6.008683	45344.22	2.295736	45.17992	0.002507	0.005719701

1.6 CMC-Stepwet DF-95

Bench-scale

100ppm CMC +Stepwet									
Surface tension									
Concentra	20	40	60	80	100	200	300	500	1000
	67.5	62.3	58.2	57.2	54	50.5	44.6	39.8	34.3
	67.8	62.5	58.7	56	54.1	50.2	45	40.2	35.2
Avg.	67.65	62.4	58.45	56.6	54.05	50.35	44.8	40	34.75
Conductivity									
Concentra	20	40	60	80	100	200	300	500	1000
	0.174	0.183	0.219	0.236	0.29	0.382	0.53	0.762	1.351
	0.172	0.187	0.217	0.222	0.292	0.384	0.529	0.766	1.349
Avg.	0.173	0.185	0.218	0.229	0.291	0.383	0.5295	0.764	1.35

100ppm CMC +Stepwet							
Concentration	RPM	30	60	90	100	180	200
20ppm	Dail Reading	7.6	9.9	11.2	12.5	15	17
	Shear stress	0.30016	0.50279	0.61732	0.73185	0.9521	1.1283
	LN(shear stress)	-1.20344	-0.68758	-0.48237	-0.31218	-0.04909	0.120712
	shear rate	52.63072	105.2614	157.8922	175.4357	315.7843	350.8715
	Vicosity	0.005703	0.004777	0.00391	0.004172	0.003015	0.003216
40ppm	Dail Reading	7.7	9.2	11.1	11.7	14.8	15.5
	Shear stress	0.30897	0.44112	0.60851	0.66137	0.93448	0.99615
	LN(shear stress)	-1.17451	-0.81844	-0.49674	-0.41344	-0.06777	-0.00386
	shear rate	52.93654	105.8731	158.8096	176.4551	317.6192	352.9103
	Vicosity	0.005837	0.004166	0.003832	0.003748	0.002942	0.002823
60ppm	Dail Reading	7.5	8.6	10.3	10.9	14.2	15.3
	Shear stress	0.29135	0.38826	0.53803	0.59089	0.88162	0.97853
	LN(shear stress)	-1.23323	-0.94608	-0.61984	-0.52613	-0.12599	-0.0217
	shear rate	52.7227	105.4454	158.1681	175.7423	316.3362	351.4847
	Vicosity	0.005526	0.003682	0.003402	0.003362	0.002787	0.002784
80ppm	Dail Reading	7.3	8.7	10.5	10.7	14.1	14.7
	Shear stress	0.27373	0.39707	0.55565	0.57327	0.87281	0.92567
	LN(shear stress)	-1.29561	-0.92364	-0.58762	-0.5564	-0.13604	-0.07724
	shear rate	52.7612	105.5224	158.2836	175.8707	316.5672	351.7413
	Vicosity	0.005188	0.003763	0.00351	0.00326	0.002757	0.002632

100ppm	Dail Reading		6.9	8.5	10.2	10.4	14.1	14.8
	Shear stress		0.23849	0.37945	0.52922	0.54684	0.87281	0.93448
	LN(shear stress)		-1.43343	-0.96903	-0.63635	-0.6036	-0.13604	-0.06777
	shear rate		52.28079	104.5616	156.8424	174.2693	313.6847	348.5386
	Vicosity		0.004562	0.003629	0.003374	0.003138	0.002782	0.002681
200ppm	Dail Reading		7.1	8.1	9.7	10.3	13.8	14.6
	Shear stress		0.25611	0.34421	0.48517	0.53803	0.84638	0.91686
	LN(shear stress)		-1.36215	-1.0665	-0.72326	-0.61984	-0.16679	-0.0868
	shear rate		52.39804	104.7961	157.1941	174.6601	314.3882	349.3203
	Vicosity		0.004888	0.003285	0.003086	0.00308	0.002692	0.002625
300ppm	Dail Reading		6.5	7.5	9.5	9.8	13.2	14
	Shear stress		0.20325	0.29135	0.46755	0.49398	0.79352	0.864
	LN(shear stress)		-1.59332	-1.23323	-0.76025	-0.70526	-0.23128	-0.14618
	shear rate		51.87107	103.7421	155.6132	172.9036	311.2264	345.8071
	Vicosity		0.003918	0.002808	0.003005	0.002857	0.00255	0.002499
500ppm	Dail Reading		6.5	7.7	9.4	9.8	12	13
	Shear stress		0.20325	0.30897	0.45874	0.49398	0.6878	0.7759
	LN(shear stress)		-1.59332	-1.17451	-0.77927	-0.70526	-0.37426	-0.25373
	shear rate		52.37938	104.7588	157.1381	174.5979	314.2763	349.1958
	Vicosity		0.00388	0.002949	0.002919	0.002829	0.002189	0.002222
1000ppm	Dail Reading		6.4	7.5	8.2	8.8	11	12.1
	Shear stress		0.19444	0.29135	0.35302	0.40588	0.5997	0.69661
	LN(shear stress)		-1.63763	-1.23323	-1.04123	-0.9017	-0.51133	-0.36153
	shear rate		52.68556	105.3711	158.0567	175.6185	316.1134	351.2371
	Vicosity		0.003691	0.002765	0.002234	0.002311	0.001897	0.001983

500ppm CMC + Stepwet DF-95										
Surface tension										
Concentration	10	20	40	60	80	100	200	300	500	1000
	66.7	64.8	61.2	58.1	56.1	51	45.4	42.3	35.4	35
	68.8	64.4	60.8	58	55.8	51	45.7	42.7	36	34.7
Avg.	67.75	64.6	61	58.05	55.95	51	45.55	42.5	35.7	34.85
Conductivity										
Concentration	10	20	40	60	80	100	200	300	500	1000
	0.607	0.648	0.658	0.66	0.698	0.697	0.813	0.943	1.145	1.714
	0.605	0.651	0.663	0.658	0.693	0.692	0.811	0.945	1.161	1.728
Avg.	0.606	0.6495	0.6605	0.659	0.6955	0.6945	0.812	0.944	1.153	1.721

500ppm CMC +Stepwet			30	60	90	100	180	200
Concentration	RPM		14	21.3	26	27	38	49.7
10ppm	Dail Reading		0.864	1.50713	1.9212	2.0093	2.9784	4.00917
	Shear stress		-0.14618	0.410207	0.65295	0.697786	1.091386	1.388584
	LN(shear stress)		52.06438	104.1288	156.1931	173.5479	312.3863	347.0959
	shear rate		0.016595	0.014474	0.0123	0.011578	0.009534	0.011551
	Vicosity							
			14.1	21.1	26.1	27.2	37.7	40.8
20ppm	Dail Reading		0.87281	1.48951	1.93001	2.02692	2.95197	3.22508
	Shear stress		-0.13604	0.398447	0.657525	0.706517	1.082473	1.170958
	LN(shear stress)		52.62169	105.2434	157.8651	175.4056	315.7302	350.8113
	shear rate		0.016587	0.014153	0.012226	0.011556	0.00935	0.009193
	Vicosity							
			13.7	21.1	26.1	27.2	37.7	40.8
40ppm	Dail Reading		0.83757	1.48951	1.93001	2.02692	2.95197	3.22508
	Shear stress		-0.17725	0.398447	0.657525	0.706517	1.082473	1.170958
	LN(shear stress)		52.47942	104.9588	157.4383	174.9314	314.8765	349.8628
	shear rate		0.01596	0.014191	0.012259	0.011587	0.009375	0.009218
	Vicosity							
			12.9	20.2	24.8	26.3	36.1	37.8
60ppm	Dail Reading		0.76709	1.41022	1.81548	1.94763	2.81101	2.96078
	Shear stress		-0.26515	0.343746	0.59635	0.666613	1.033544	1.085453
	LN(shear stress)		52.41138	104.8228	157.2341	174.7046	314.4683	349.4092
	shear rate		0.014636	0.013453	0.011546	0.011148	0.008939	0.008474

80ppm	Dail Reading	0.7759	1.28688	1.71857	1.82429	2.67005	2.83744
	Shear stress	-0.25373	0.252221	0.541493	0.601191	0.982097	1.042902
	LN(shear stress)	52.57925	105.1585	157.7378	175.2642	315.4755	350.5283
	shear rate	0.014757	0.012238	0.010895	0.010409	0.008464	0.008095
	Vicosity						
		12.3	17.4	21.9	24.1	32.6	35.2
100ppm	Dail Reading	0.71423	1.16354	1.55999	1.75381	2.50266	2.73172
	Shear stress	-0.33655	0.151467	0.444679	0.561791	0.917354	1.004931
	LN(shear stress)	52.41471	104.8294	157.2441	174.7157	314.4883	349.4314
	shear rate	0.013627	0.011099	0.009921	0.010038	0.007958	0.007818
	Vicosity						
		11	15.2	17.8	20.5	29	31.7
200ppm	Dail Reading	0.5997	0.96972	1.19878	1.43665	2.1855	2.42337
	Shear stress	-0.51133	-0.03075	0.181304	0.362314	0.781845	0.885159
	LN(shear stress)	52.20593	104.4119	156.6178	174.0198	313.2356	348.0395
	shear rate	0.011487	0.009287	0.007654	0.008256	0.006977	0.006963
	Vicosity						
		10.2	14.3	18	18.3	27	29.3
300ppm	Dail Reading	0.52922	0.89043	1.2164	1.24283	2.0093	2.21193
	Shear stress	-0.63635	-0.11605	0.195896	0.217391	0.697786	0.793865
	LN(shear stress)	52.14941	104.2988	156.4482	173.8314	312.8965	347.6627
	shear rate	0.010148	0.008537	0.007775	0.00715	0.006422	0.006362
	Vicosity						
		9.7	13.1	16.1	17.2	25.4	27
500ppm	Dail Reading	0.48517	0.78471	1.04901	1.14592	1.86834	2.0093
	Shear stress	-0.72326	-0.24244	0.047847	0.136208	0.62505	0.697786
	LN(shear stress)	52.09858	104.1972	156.2957	173.6619	312.5915	347.3239
	shear rate	0.009313	0.007531	0.006712	0.006599	0.005977	0.005785
	Viscosity						
		9.2	11.7	14.9	15.4	22	24.1
1000ppm	Dail Reading	0.44112	0.66137	0.94329	0.98734	1.5688	1.75381
	Shear stress	-0.81844	-0.41344	-0.05838	-0.01274	0.450311	0.561791
	LN(shear stress)	52.22355	104.4471	156.6707	174.0785	313.3413	348.157
	shear rate	0.008447	0.006332	0.006021	0.005672	0.005007	0.005037

Flow Data

500ppm CMC with 30ppm Stepwet in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.16	1	2	1.35	0.25224	0.663684	1295.558	0.062835	2.619666	0.011913	0.000253
1.173	1	2	1.427	0.272182	0.716155	1431.962	0.072237	3.011634	0.011762	0.000273
1.212	1	2	1.513	0.332008	0.873567	1859.745	0.082737	3.449416	0.009054	0.000333
1.255	1	2	1.611	0.39797	1.047124	2360.443	0.094703	3.948284	0.007213	0.000399
1.313	1	2	1.84	0.486942	1.281223	3078.049	0.122664	5.114007	0.00624	0.000488
1.383	1	2	2.189	0.594322	1.563758	4000.677	0.165277	6.89059	0.005644	0.000596
1.472	1	2	2.617	0.730848	1.92298	5251.475	0.217536	9.069321	0.004913	0.000733
1.546	1	2	3.025	0.844364	2.221659	6349.988	0.267353	11.14624	0.004523	0.000847
1.574	1	2	3.239	0.887316	2.334672	6778.323	0.293482	12.23561	0.004496	0.00089
1.601	1	2	3.39	0.928734	2.44365	7197.609	0.311919	13.00427	0.004362	0.000932
1.616	1	2	3.481	0.951744	2.504193	7433.127	0.32303	13.46751	0.004302	0.000955
1.631	1	2	3.605	0.974754	2.564736	7670.448	0.338171	14.09873	0.004293	0.000978
1.767	1	2	4.547	1.183378	3.11366	9899.92	0.453189	18.89397	0.003904	0.001187
1.853	1	3	1.423	1.315302	3.460773	11376.81	0.507976	21.17813	0.003542	0.001319
1.923	1	3	1.482	1.422682	3.743307	12614.18	0.582204	24.27278	0.00347	0.001427
2.043	1	3	1.583	1.606762	4.227652	14804.04	0.709272	29.5704	0.003314	0.001612
2.248	1	3	1.772	1.921232	5.055073	18728.72	0.947053	39.48377	0.003095	0.001927
2.374	1	3	1.91	2.114516	5.563635	21246.04	1.120671	46.7221	0.003023	0.002121
2.552	1	3	2.11	2.387568	6.282079	24926.94	1.372291	57.21244	0.002904	0.002395
2.749	1	3	2.343	2.689766	7.077211	29158.34	1.665428	69.43368	0.002777	0.002698
2.98	1	3	2.642	3.04412	8.009574	34314.11	2.0416	85.11673	0.002658	0.003053
3.173	1	3	2.916	3.340182	8.788561	38770.59	2.38632	99.48849	0.00258	0.00335
3.377	1	3	3.225	3.653118	9.611947	43618.51	2.775073	115.6961	0.002508	0.003664
3.545	1	3	3.483	3.91083	10.29003	47711.1	3.099662	129.2286	0.002445	0.003923
3.733	1	3	3.781	4.199222	11.04883	52392.77	3.474576	144.8592	0.002377	0.004212
3.769	1	3	3.837	4.254446	11.19414	53301.12	3.54503	147.7965	0.002362	0.004267

500ppm CMC with 30ppm Stepwet in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.057	2	2	1.023	0.094238	0.099277	145.5367	0.022908	0.450834	0.091622	9.45216E-05
1.126	2	2	1.074	0.200084	0.210783	391.8823	0.029135	0.573382	0.02585	0.000200686
1.216	2	2	1.183	0.338144	0.356226	781.5682	0.042444	0.835301	0.013185	0.000339161
1.322	2	2	1.367	0.500748	0.527525	1310.086	0.064911	1.277438	0.009195	0.000502255
1.393	2	2	1.532	0.609662	0.642263	1697.243	0.085057	1.673919	0.008128	0.000611496
1.482	2	2	1.744	0.746188	0.78609	2214.113	0.110942	2.183338	0.007077	0.000748433
1.558	2	2	1.946	0.862772	0.908908	2680.066	0.135607	2.668728	0.006471	0.000865368
1.697	2	2	2.364	1.075998	1.133536	3583.702	0.186644	3.673148	0.005726	0.001079236
1.817	2	2	2.767	1.260078	1.327459	4411.269	0.235851	4.641524	0.005276	0.00126387
1.876	2	2	2.988	1.350584	1.422805	4832.757	0.262835	5.172569	0.005118	0.001354648
1.915	2	2	3.102	1.41041	1.48583	5116.341	0.276754	5.446502	0.004942	0.001414654
1.926	2	2	3.169	1.427284	1.503606	5197.022	0.284935	5.607498	0.004968	0.001431579
2.012	2	2	3.521	1.559208	1.642585	5838.016	0.327914	6.453325	0.004791	0.0015639
2.135	2	2	3.982	1.74789	1.841357	6784.725	0.384202	7.561071	0.004467	0.001753149
2.224	2	2	4.322	1.884416	1.985183	7490.37	0.425716	8.378063	0.004258	0.001890086
2.36	2	2	4.95	2.09304	2.204963	8599.944	0.502395	9.887096	0.004073	0.002099338
2.5	2	3	1.461	2.3078	2.431207	9779.22	0.555784	10.93779	0.003707	0.002314744
2.683	2	3	1.552	2.588522	2.72694	11373.44	0.670271	13.19089	0.003553	0.002596311
2.902	2	3	1.67	2.924468	3.080851	13354.02	0.818727	16.11249	0.0034	0.002933268
3.044	2	3	1.744	3.142296	3.310327	14677.73	0.911826	17.94468	0.00328	0.003151751
3.244	2	3	1.848	3.449096	3.633533	16591.5	1.042669	20.51964	0.003113	0.003459474
3.506	2	3	2.025	3.851004	4.056932	19180.58	1.265353	24.90204	0.003031	0.003862592
3.681	2	3	2.123	4.119454	4.339737	20958.67	1.388646	27.32846	0.002906	0.00413185
3.884	2	3	2.258	4.430856	4.667791	23067.46	1.55849	30.67096	0.00282	0.004444189
4.088	2	3	2.387	4.743792	4.997461	25234.32	1.720785	33.86491	0.002716	0.004758066
4.319	2	3	2.562	5.098146	5.370764	27742.93	1.940952	38.19779	0.002652	0.005113486
4.562	2	3	2.733	5.470908	5.763459	30441.89	2.156087	42.43164	0.002559	0.00548737

500ppm CMC with 100ppm Stepwet in 1inch pipe									
Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1	2	1.229	0.161734	0.425463	873.266	0.048061	2.003716	0.022167	0.000162
1	2	1.324	0.26758	0.703905	1675.599	0.05966	2.487313	0.010053	0.000268
1	2	1.57	0.38263	1.00656	2662.093	0.089697	3.739574	0.007392	0.000384
1	2	1.783	0.460864	1.212365	3386.903	0.115704	4.823849	0.006572	0.000462
1	2	2.205	0.595856	1.56748	4722.99	0.167231	6.972038	0.005683	0.000598
1	2	2.635	0.715508	1.882241	5985.316	0.219734	9.16095	0.005178	0.000718
1	2	3.05	0.815218	2.144541	7086.42	0.270405	11.2735	0.004909	0.000818
1	2	3.284	0.871976	2.293851	7731.489	0.298976	12.46468	0.004744	0.000875
1	2	3.557	0.931802	2.451231	8424.936	0.33231	13.85438	0.004618	0.000935
1	2	3.747	0.97322	2.560187	8912.806	0.355509	14.82158	0.004528	0.000976
1	2	4.598	1.146562	3.016187	11019.41	0.459416	19.15359	0.004216	0.00115
1	3	1.412	1.247806	3.282523	12294.95	0.494137	20.60116	0.003829	0.001252
1	3	1.482	1.375128	3.61746	13942.65	0.582204	24.27278	0.003715	0.001379
1	3	1.558	1.516256	3.988717	15822.17	0.67782	28.25911	0.003557	0.001521
1	3	1.704	1.727948	4.545601	18738.46	0.861502	35.91705	0.003481	0.001733
1	3	1.821	1.921232	5.054061	21495.12	1.0087	42.0539	0.003297	0.001927
1	3	2.129	2.329276	6.127476	27580.68	1.396195	58.20902	0.003105	0.002336
1	3	2.47	2.728116	7.176679	33841.92	1.825207	76.09504	0.002959	0.002736
1	3	2.705	2.99043	7.866731	38112.17	2.120861	88.42119	0.002861	0.002999
1	3	3.221	3.50432	9.218588	46796.05	2.77004	115.4863	0.002721	0.003515
1	3	3.634	3.900092	10.25972	53747.89	3.289635	137.1488	0.002609	0.003912
1	3	3.891	4.105648	10.80046	57442.77	3.612967	150.6289	0.002586	0.004118
1	3	3.965	4.173144	10.97802	58668.08	3.706067	154.5103	0.002567	0.004186

500ppm CMC with 100ppm Stepwet in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.04	2	2	1.015	0.06816	0.07179	120.5276	0.021932	0.43161	0.167708	6.83651E-05
1.13	2	2	1.053	0.20622	0.217204	505.1675	0.026571	0.522921	0.022197	0.000206841
1.182	2	2	1.134	0.285988	0.301221	771.3691	0.036461	0.717558	0.015837	0.000286849
1.276	2	2	1.287	0.430184	0.453097	1308.482	0.055143	1.085204	0.010586	0.000431478
1.377	2	2	1.498	0.585118	0.616283	1948.433	0.080906	1.59222	0.008395	0.000586879
1.439	2	2	1.63	0.680226	0.716457	2367.838	0.097023	1.909405	0.007449	0.000682273
1.509	2	2	1.812	0.787606	0.829556	2862.517	0.119245	2.346737	0.006829	0.000789976
1.593	2	2	2.045	0.916462	0.965275	3482.784	0.147695	2.906617	0.006247	0.00091922
1.682	2	2	2.338	1.052988	1.109073	4168.603	0.18347	3.610672	0.005878	0.001056156
1.779	2	2	2.651	1.201786	1.265797	4946.453	0.221687	4.362786	0.005453	0.001205402
1.83	2	2	2.864	1.28002	1.348198	5367.19	0.247694	4.874607	0.005371	0.001283872
1.928	2	2	3.204	1.430352	1.506537	6196.85	0.289208	5.6916	0.005022	0.001434656
2.02	2	2	3.588	1.57148	1.655182	6999.513	0.336095	6.614321	0.004835	0.001576209
2.087	2	2	3.882	1.674258	1.763434	7597.686	0.371992	7.320779	0.004714	0.001679296
2.193	2	2	4.361	1.836862	1.934699	8566.162	0.430478	8.471777	0.004533	0.001842389
2.282	2	2	4.78	1.973388	2.078496	9399.152	0.481638	9.4786	0.004394	0.001979326
2.573	2	3	1.519	2.419782	2.548667	12238.43	0.628754	12.37383	0.003815	0.002427063
2.768	2	3	1.627	2.718912	2.863729	14231.37	0.764629	15.04784	0.003675	0.002727093
2.942	2	3	1.722	2.985828	3.144862	16065.32	0.884148	17.39997	0.003523	0.002994812
3.156	2	3	1.847	3.314104	3.490623	18387.71	1.041411	20.49488	0.003368	0.003324076
3.324	2	3	1.952	3.571816	3.762061	20259.34	1.173511	23.09461	0.003268	0.003582564
3.504	2	3	2.109	3.847936	4.052888	22309.23	1.371033	26.98182	0.00329	0.003859515
3.765	2	3	2.253	4.24831	4.474588	25358.8	1.552199	30.54717	0.003055	0.004261093
4.022	2	3	2.438	4.642548	4.889824	28445.6	1.784948	35.12764	0.002942	0.004656518
4.247	2	3	2.622	4.987698	5.253357	31212.43	2.016438	39.68335	0.00288	0.005002706
4.462	2	3	2.783	5.317508	5.600734	33909.57	2.218992	43.6696	0.002788	0.005333509
4.568	2	3	2.879	5.480112	5.771999	35257.76	2.33977	46.0465	0.002768	0.005496602

500ppm CMC with 300ppm Stepwet in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.083	1	2	1.113	0.134122	0.352685	904.5593	0.033897	1.413219	0.022743	0.000135
1.178	1	2	1.353	0.279852	0.735894	2271.086	0.063201	2.634937	0.00974	0.000281
1.249	1	2	1.587	0.388766	1.022292	3426.982	0.091773	3.826113	0.007329	0.00039
1.325	1	2	1.93	0.50535	1.328859	4758.544	0.133653	5.572152	0.006317	0.000507
1.398	1	2	2.307	0.617332	1.623325	6113.238	0.179685	7.491268	0.005691	0.000619
1.483	1	2	2.791	0.747722	1.966196	7770.182	0.238781	9.955067	0.005155	0.00075
1.558	1	2	3.271	0.862772	2.26873	9294.488	0.297389	12.3985	0.004822	0.000865
1.665	1	2	4.064	1.02691	2.700344	11558.25	0.394214	16.43527	0.004512	0.00103
1.72	1	2	4.5	1.11128	2.922202	12758.83	0.44745	18.65472	0.004373	0.001115
1.824	1	3	1.435	1.270816	3.341715	15091.34	0.523074	21.80755	0.003909	0.001275
1.932	1	3	1.536	1.436488	3.777363	17592.89	0.650142	27.10517	0.003803	0.001441
2.02	1	3	1.619	1.57148	4.132336	19686.03	0.754564	31.45866	0.003688	0.001576
2.112	1	3	1.708	1.712608	4.503444	21923.22	0.866535	36.12686	0.003566	0.001718
2.263	1	3	1.877	1.944242	5.112544	25695.55	1.079154	44.9912	0.003446	0.00195
2.431	1	3	2.067	2.201954	5.790219	30027.34	1.318193	54.95701	0.003281	0.002209
2.648	1	3	2.349	2.534832	6.665549	35813.01	1.672977	69.74839	0.003143	0.002542
2.835	1	3	2.625	2.82169	7.419866	40955.8	2.020213	84.22505	0.003062	0.00283
3.097	1	3	3.016	3.223598	8.476716	48383.52	2.51213	104.7337	0.002918	0.003233
3.446	1	3	3.58	3.758964	9.884505	58642.61	3.221698	134.3164	0.002752	0.00377
3.611	1	3	3.896	4.012074	10.55008	63625.99	3.619258	150.8911	0.002714	0.004024
3.737	1	3	4.125	4.205358	11.05833	67485.4	3.907363	162.9026	0.002667	0.004218

500ppm CMC with 300ppm Stepwet in 1.5inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.054	2	2	1.017	0.089636	0.094372	244.6795	0.022176	0.436416	0.098091	8.99057E-05
1.129	2	2	1.079	0.204686	0.215502	687.7466	0.029746	0.585397	0.025233	0.000205302
1.233	2	2	1.21	0.364222	0.383468	1414.739	0.045741	0.900179	0.012254	0.000365318
1.327	2	2	1.38	0.508418	0.535283	2147.715	0.066498	1.308676	0.009143	0.000509948
1.457	2	2	1.68	0.707838	0.745241	3249.734	0.103128	2.029551	0.007315	0.000709968
1.609	2	2	2.092	0.941006	0.99073	4641.077	0.153433	3.019554	0.006158	0.000943838
1.855	2	2	2.942	1.31837	1.388034	7077.979	0.257218	5.062035	0.00526	0.001322337
1.986	2	2	3.459	1.519324	1.599607	8453.26	0.320344	6.304344	0.004932	0.001523896
2.056	2	2	3.724	1.626704	1.712661	9207.555	0.3527	6.941117	0.004737	0.001631599
2.201	2	2	4.367	1.849134	1.946845	10809.56	0.431211	8.486194	0.004482	0.001854698
2.258	2	2	4.683	1.936572	2.038903	11453.07	0.469794	9.245517	0.004452	0.001942399
2.336	2	3	1.402	2.056224	2.164877	12345.52	0.481556	9.47699	0.004048	0.002062411
2.464	2	3	1.473	2.252576	2.371605	13838.35	0.570881	11.2349	0.003999	0.002259354
2.661	2	3	1.577	2.554774	2.689771	16199.92	0.701724	13.80987	0.003821	0.002562461
2.869	2	3	1.696	2.873846	3.025704	18770.83	0.851438	16.75623	0.003664	0.002882493
3.067	2	3	1.812	3.177578	3.345485	21286.01	0.997377	19.62831	0.003511	0.003187139
3.131	2	3	1.84	3.275754	3.448849	22112.31	1.032604	20.32157	0.00342	0.003285611
3.309	2	3	1.975	3.548806	3.736329	24442.94	1.202448	23.66408	0.003393	0.003559484
3.482	2	3	2.086	3.814188	4.015735	26751.83	1.342097	26.41236	0.003279	0.003825665
3.646	2	3	2.198	4.065764	4.280604	28978.3	1.483004	29.1854	0.003188	0.004077998
3.861	2	3	2.369	4.395574	4.627842	31949.85	1.698139	33.41925	0.003124	0.0044088
4.117	2	3	2.548	4.788278	5.041297	35561.74	1.923339	37.85116	0.002981	0.004802686
4.385	2	3	2.767	5.19939	5.474132	39423.63	2.198863	43.27345	0.002891	0.005215035
4.675	2	3	3.004	5.64425	5.942499	43689.89	2.497032	49.14141	0.002786	0.005661234
4.875	2	3	3.187	5.95105	6.265511	46682.26	2.727265	53.67237	0.002737	0.005968957

1.7 CMC-Amphosol

Bench-scale

100ppm CMC + Amphosol											
Surface tension											
Concentra	1	5	10	20	30	50	70	100	120	150	200
	67.1	53.3	41.9	38.1	37.1	35	33.6	33.2	33	32.9	33.1
	66.2	52.9	41.6	37.7	37	34.9	34.1	33.4	33.4	33	33.1
Avg.	66.65	53.1	41.75	37.9	34.95	33.85	33.3	33.2	32.95	32.95	33.1
Conductivity											
Concentra	1	5	10	20	30	50	70	100	120	150	200
	0.125	0.127	0.134	0.145	0.163	0.175	0.17	0.2	0.206	0.239	0.273
	0.122	0.128	0.135	0.144	0.163	0.174	0.17	0.202	0.208	0.24	0.272
Avg.	0.1235	0.1275	0.1345	0.1445	0.163	0.1745	0.17	0.201	0.207	0.2395	0.2725

100ppm CMC +Amphosol							
	RPM	30	60	90	100	180	200
1ppm	Dail Reading	8.5	10.7	12.4	12.8	17.2	18.1
	Shear stress	0.37945	0.57327	0.72304	0.75828	1.14592	1.22521
	LN(shear stress)	-0.96903	-0.5564	-0.32429	-0.2767	0.136208	0.203112
	shear rate	53.07924	106.1585	159.2377	176.9308	318.4755	353.8616
	Vicosity	0.007149	0.0054	0.004541	0.004286	0.003598	0.003462
5ppm	Dail Reading	8	10.5	12	12.6	17	17.8
	Shear stress	0.3354	0.55565	0.6878	0.74066	1.1283	1.19878
	LN(shear stress)	-1.09243	-0.58762	-0.37426	-0.30021	0.120712	0.181304
	shear rate	52.68623	105.3725	158.0587	175.6208	316.1174	351.2415
	Vicosity	0.006366	0.005273	0.004352	0.004217	0.003569	0.003413
10ppm	Dail Reading	8	10.2	11.9	12.5	16.8	17.3
	Shear stress	0.3354	0.52922	0.67899	0.73185	1.11068	1.15473
	LN(shear stress)	-1.09243	-0.63635	-0.38715	-0.31218	0.104972	0.143867
	shear rate	52.7545	105.509	158.2635	175.8483	316.527	351.6967
	Vicosity	0.006358	0.005016	0.00429	0.004162	0.003509	0.003283
20ppm	Dail Reading	7.8	9.8	11.6	12.4	16.9	17.3
	Shear stress	0.31778	0.49398	0.65256	0.72304	1.11949	1.15473
	LN(shear stress)	-1.1464	-0.70526	-0.42685	-0.32429	0.112873	0.143867
	shear rate	52.47408	104.9482	157.4222	174.9136	314.8445	349.8272
	Vicosity	0.006056	0.004707	0.004145	0.004134	0.003556	0.003301
30ppm	Dail Reading	7.5	9.2	11.7	11.8	15.6	16.6
	Shear stress	0.29135	0.44112	0.66137	0.67018	1.00496	1.09306
	LN(shear stress)	-1.23323	-0.81844	-0.41344	-0.40021	0.004948	0.088981
	shear rate	52.39871	104.7974	157.1961	174.6624	314.3922	349.3247
	Vicosity	0.00556	0.004209	0.004207	0.003837	0.003197	0.003129
50ppm	Dail Reading	6.7	8.8	10.4	10.8	14.3	15.4
	Shear stress	0.22087	0.40588	0.54684	0.58208	0.89043	0.98734
	LN(shear stress)	-1.51018	-0.9017	-0.6036	-0.54115	-0.11605	-0.01274
	shear rate	51.99569	103.9914	155.9871	173.319	311.9741	346.6379
	Vicosity	0.004248	0.003903	0.003506	0.003358	0.002854	0.002848

70ppm	Dail Reading	6.7	8.5	10.3	10.7	14.2	15.2
	Shear stress	0.22087	0.37945	0.53803	0.57327	0.88162	0.96972
	LN(shear stress)	-1.51018	-0.96903	-0.61984	-0.5564	-0.12599	-0.03075
	shear rate	51.98872	103.9774	155.9662	173.2957	311.9323	346.5915
	Vicosity	0.004248	0.003649	0.00345	0.003308	0.002826	0.002798
100ppm	Dail Reading	6.7	8.4	10.1	10.5	13.9	15
	Shear stress	0.22087	0.37064	0.52041	0.55565	0.85519	0.9521
	LN(shear stress)	-1.51018	-0.99252	-0.65314	-0.58762	-0.15643	-0.04909
	shear rate	51.8459	103.6918	155.5377	172.8197	311.0754	345.6394
	Vicosity	0.00426	0.003574	0.003346	0.003215	0.002749	0.002755
120ppm	Dail Reading	6.6	8.4	9.9	10.4	13.6	14.8
	Shear stress	0.21206	0.37064	0.50279	0.54684	0.82876	0.93448
	LN(shear stress)	-1.55089	-0.99252	-0.68758	-0.6036	-0.18782	-0.06777
	shear rate	52.03052	104.061	156.0916	173.4351	312.1831	346.8702
	Vicosity	0.004076	0.003562	0.003221	0.003153	0.002655	0.002694
150ppm	Dail Reading	6.6	8.5	10.2	10.6	13.5	14.7
	Shear stress	0.21206	0.37945	0.52922	0.56446	0.81995	0.92567
	LN(shear stress)	-1.55089	-0.96903	-0.63635	-0.57189	-0.19851	-0.07724
	shear rate	52.06604	104.1321	156.1981	173.5535	312.3962	347.1069
	Vicosity	0.004073	0.003644	0.003388	0.003252	0.002625	0.002667
200ppm	Dail Reading	6.5	8.2	9.8	10.1	13.3	14
	Shear stress	0.20325	0.35302	0.49398	0.52041	0.80233	0.864
	LN(shear stress)	-1.59332	-1.04123	-0.70526	-0.65314	-0.22024	-0.14618
	shear rate	52.07368	104.1474	156.221	173.5789	312.4421	347.1578
	Vicosity	0.003903	0.00339	0.003162	0.002998	0.002568	0.002489
300ppm	Dail Reading	6.4	7.9	9.3	9.7	12.3	13.6
	Shear stress	0.19444	0.32659	0.44993	0.48517	0.71423	0.82876
	LN(shear stress)	-1.63763	-1.11905	-0.79866	-0.72326	-0.33655	-0.18782
	shear rate	52.60431	105.2086	157.8129	175.3477	315.6259	350.6954
	Vicosity	0.003696	0.003104	0.002851	0.002767	0.002263	0.002363

500ppm CMC + Amphosol											
Surface tension											
Concentration	1	5	10	20	30	50	70	100	120	150	200
	63	54.4	49.8	39.5	38.7	37.2	36.1	34.1	33.5	33.1	32.7
	61.7	53.6	49	39.6	38.6	36.3	35.2	34.5	33.7	32.8	32.2
Avg.	62.35	54	49.4	39.55	38.65	36.75	35.65	34.3	33.6	32.95	32.45
Conductivity											
Concentration	1	5	10	20	30	50	70	100	120	150	200
	0.562	0.569	0.58	0.587	0.583	0.599	0.59	0.628	0.648	0.672	0.723
	0.56	0.57	0.585	0.585	0.586	0.597	0.596	0.629	0.657	0.657	0.72
Avg.	0.561	0.5695	0.5825	0.586	0.5845	0.598	0.593	0.6285	0.653	0.6645	0.7215

500ppm CMC +Amphosol											
	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reading	4.9	5.7	6	7.3	15.3	21.4	27	27.6	37.9	41.1
	Shear stress	0.0623	0.1328	0.1592	0.2737	0.9785	1.516	2.0093	2.062	2.9696	3.2515
	LN(shear stress)	-2.776	-2.019	-1.838	-1.296	-0.022	0.416	0.6978	0.724	1.0884	1.1791
	shear rate	1.57	3.14	5.2334	10.467	52.334	104.7	157	174.4	314	348.89
	Vicosity	0.0397	0.0423	0.0304	0.0262	0.0187	0.014	0.0128	0.012	0.0095	0.0093
5ppm	Dail Reading	5.5	6	6.4	8	14.7	21.5	27.2	28	39.4	40.7
	Shear stress	0.1152	0.1592	0.1944	0.3354	0.9257	1.525	2.0269	2.097	3.1017	3.2163
	LN(shear stress)	-2.162	-1.838	-1.638	-1.092	-0.077	0.422	0.7065	0.741	1.132	1.1682
	shear rate	1.5807	3.1614	5.269	10.538	52.69	105.4	158.07	175.6	316.14	351.27
	Vicosity	0.0728	0.0504	0.0369	0.0318	0.0176	0.014	0.0128	0.012	0.0098	0.0092
10ppm	Dail Reading	5.4	5.9	6.4	7.1	14.8	22.2	28	29.3	39.8	42.3
	Shear stress	0.1063	0.1504	0.1944	0.2561	0.9345	1.586	2.0974	2.212	3.137	3.3572
	LN(shear stress)	-2.241	-1.895	-1.638	-1.362	-0.068	0.461	0.7407	0.794	1.1433	1.2111
	shear rate	1.5716	3.1431	5.2385	10.477	52.385	104.8	157.16	174.6	314.31	349.24
	Vicosity	0.0677	0.0478	0.0371	0.0244	0.0178	0.015	0.0133	0.013	0.01	0.0096
20ppm	Dail Reading	5.3	5.9	6.3	7.2	14.7	20.6	25.9	27	39.6	39.7
	Shear stress	0.0975	0.1504	0.1856	0.2649	0.9257	1.445	1.9124	2.009	3.1194	3.1282
	LN(shear stress)	-2.328	-1.895	-1.684	-1.328	-0.077	0.368	0.6484	0.698	1.1376	1.1404
	shear rate	1.5748	3.1496	5.2494	10.499	52.494	105	157.48	175	314.96	349.96
	Vicosity	0.0619	0.0477	0.0354	0.0252	0.0176	0.014	0.0121	0.011	0.0099	0.0089
30ppm	Dail Reading	5.7	6.1	6.6	7.7	14.6	20.8	26	26.8	38.1	39.4
	Shear stress	0.1328	0.168	0.2121	0.309	0.9169	1.463	1.9212	1.992	2.9872	3.1017
	LN(shear stress)	-2.019	-1.784	-1.551	-1.175	-0.087	0.381	0.6529	0.689	1.0943	1.132
	shear rate	1.5845	3.1691	5.2818	10.564	52.818	105.6	158.45	176.1	316.91	352.12
	Vicosity	0.0838	0.053	0.0401	0.0292	0.0174	0.014	0.0121	0.011	0.0094	0.0088

50ppm	Dail Reading	5.2	6	6.7	7.3	14.2	19.1	24	26.3	36.2	39.3
	Shear stress	0.0887	0.1592	0.2209	0.2737	0.8816	1.313	1.745	1.948	2.8198	3.0929
	LN(shear stress)	-2.422	-1.838	-1.51	-1.296	-0.126	0.273	0.5568	0.667	1.0367	1.1291
	shear rate	1.585	3.17	5.2833	10.567	52.833	105.7	158.5	176.1	317	352.22
	Vicosity	0.056	0.0502	0.0418	0.0259	0.0167	0.012	0.011	0.011	0.0089	0.0088
70ppm	Dail Reading	4.9	5.5	6.8	7.5	13	19	22.9	25.7	33.8	37.3
	Shear stress	0.0623	0.1152	0.2297	0.2914	0.7759	1.305	1.6481	1.895	2.6084	2.9167
	LN(shear stress)	-2.776	-2.162	-1.471	-1.233	-0.254	0.266	0.4996	0.639	0.9587	1.0705
	shear rate	1.5916	3.1831	5.3052	10.61	53.052	106.1	159.16	176.8	318.31	353.68
	Vicosity	0.0391	0.0362	0.0433	0.0275	0.0146	0.012	0.0104	0.011	0.0082	0.0082
100ppm	Dail Reading	5.8	6.2	6.6	7.1	14.1	19.9	25.1	26.9	37	39.5
	Shear stress	0.1416	0.1768	0.2121	0.2561	0.8728	1.384	1.8419	2	2.8903	3.1106
	LN(shear stress)	-1.955	-1.733	-1.551	-1.362	-0.136	0.325	0.6108	0.693	1.0614	1.1348
	shear rate	1.5798	3.1597	5.2661	10.532	52.661	105.3	157.98	175.5	315.97	351.07
	Vicosity	0.0896	0.056	0.0403	0.0243	0.0166	0.013	0.0117	0.011	0.0091	0.0089
120ppm	Dail Reading	5.7	6.5	6.9	7.8	13.3	18.8	24	24.8	37.1	39.2
	Shear stress	0.1328	0.2033	0.2385	0.3178	0.8023	1.287	1.745	1.815	2.8991	3.0841
	LN(shear stress)	-2.019	-1.593	-1.433	-1.146	-0.22	0.252	0.5568	0.596	1.0644	1.1263
	shear rate	1.5921	3.1842	5.307	10.614	53.07	106.1	159.21	176.9	318.42	353.8
	Vicosity	0.0834	0.0638	0.0449	0.0299	0.0151	0.012	0.011	0.01	0.0091	0.0087
150ppm	Dail Reading	5.6	6.2	6.4	7.1	13.2	19	24.9	25.1	35.4	37.5
	Shear stress	0.124	0.1768	0.1944	0.2561	0.7935	1.305	1.8243	1.842	2.7493	2.9344
	LN(shear stress)	-2.088	-1.733	-1.638	-1.362	-0.231	0.266	0.6012	0.611	1.0114	1.0765
	shear rate	1.5801	3.1603	5.2671	10.534	52.671	105.3	158.01	175.6	316.03	351.14
	Vicosity	0.0784	0.056	0.0369	0.0243	0.0151	0.012	0.0115	0.01	0.0087	0.0084
200ppm	Dail Reading	5.5	6.1	6.4	7.3	12.7	18.5	22.4	23.5	32.9	35.2
	Shear stress	0.1152	0.168	0.1944	0.2737	0.7495	1.26	1.604	1.701	2.5291	2.7317
	LN(shear stress)	-2.162	-1.784	-1.638	-1.296	-0.288	0.231	0.4725	0.531	0.9279	1.0049
	shear rate	1.5876	3.1752	5.292	10.584	52.92	105.8	158.76	176.4	317.52	352.8
	Vicosity	0.0725	0.0529	0.0367	0.0259	0.0142	0.012	0.0101	0.01	0.008	0.0077
300ppm	Dail Reading	5.2	5.8	6.2	7	12.3	18	21.9	22	31.1	33.8
	Shear stress	0.0887	0.1416	0.1768	0.2473	0.7142	1.216	1.56	1.569	2.3705	2.6084
	LN(shear stress)	-2.422	-1.955	-1.733	-1.397	-0.337	0.196	0.4447	0.45	0.8631	0.9587
	shear rate	1.5905	3.1811	5.3018	10.604	53.018	106	159.05	176.7	318.11	353.45
	Vicosity	0.0558	0.0445	0.0334	0.0233	0.0135	0.011	0.0098	0.009	0.0075	0.0074

700ppm CMC + Amphosol											
Surface tension											
Concentration	1	5	10	20	30	50	70	100	120	150	200
	67	60.3	58.8	47.3	37.2	35.1	34	35.6	33.4	33	32.6
	67.2	60.7	57.9	47.2	35.3	35.3	34.2	35	33	32	32.2
Avg.	67.1	60.5	58.35	47.25	36.25	34.1	35.3	33.2	32.5	32.5	32.4
Conductivity											
Concentration	1	5	10	20	30	50	70	100	120	150	200
	0.758	0.762	0.777	0.79	0.798	0.812	0.834	0.844	0.863	0.882	0.942
	0.757	0.761	0.776	0.788	0.799	0.818	0.832	0.85	0.856	0.88	0.945
Avg.	0.7575	0.7615	0.7765	0.789	0.7985	0.815	0.833	0.847	0.8595	0.881	0.9435

700ppm CMC +Amphosol											
	RPM	0.9	1.8	3	6	30	60	90	100	180	200
1ppm	Dail Reading	6.6	7	7.7	8.3	17	25.4	31.8	33.4	47.6	49.9
	Shear stress	0.2121	0.2473	0.309	0.3618	1.1283	1.8683	2.4322	2.5731	3.8242	4.0268
	LN(shear stress)	-1.551	-1.397	-1.175	-1.017	0.1207	0.6251	0.8888	0.9451	1.3413	1.393
	shear rate	1.6008	3.2015	5.3359	10.672	53.359	106.72	160.08	177.86	320.15	355.72
	Vicosity	0.1325	0.0772	0.0579	0.0339	0.0211	0.0175	0.0152	0.0145	0.0119	0.0113
5ppm	Dail Reading	7.1	8.3	7.7	8.5	19	26.1	33.2	34.5	49.2	50.8
	Shear stress	0.2561	0.3618	0.309	0.3795	1.3045	1.93	2.5555	2.6701	3.9651	4.1061
	LN(shear stress)	-1.362	-1.017	-1.175	-0.969	0.2658	0.6575	0.9383	0.9821	1.3775	1.4125
	shear rate	1.6088	3.2177	5.3628	10.726	53.628	107.26	160.88	178.76	321.77	357.52
	Vicosity	0.1592	0.1125	0.0576	0.0354	0.0243	0.018	0.0159	0.0149	0.0123	0.0115
10ppm	Dail Reading	6.9	7.8	8.2	9.1	18.5	27.2	34	35.5	50.2	52.2
	Shear stress	0.2385	0.3178	0.353	0.4323	1.2605	2.0269	2.626	2.7582	4.0532	4.2294
	LN(shear stress)	-1.433	-1.146	-1.041	-0.839	0.2315	0.7065	0.9655	1.0146	1.3995	1.4421
	shear rate	1.6087	3.2173	5.3622	10.724	53.622	107.24	160.87	178.74	321.73	357.48
	Vicosity	0.1483	0.0988	0.0658	0.0403	0.0235	0.0189	0.0163	0.0154	0.0126	0.0118
20ppm	Dail Reading	6.5	7.2	7.8	8	18.3	26.6	34.1	36.2	51	53.6
	Shear stress	0.2033	0.2649	0.3178	0.3354	1.2428	1.9741	2.6348	2.8198	4.1237	4.3528
	LN(shear stress)	-1.593	-1.328	-1.146	-1.092	0.2174	0.6801	0.9688	1.0367	1.4168	1.4708
	shear rate	1.5949	3.1898	5.3163	10.633	53.163	106.33	159.49	177.21	318.98	354.42
	Vicosity	0.1274	0.0831	0.0598	0.0315	0.0234	0.0186	0.0165	0.0159	0.0129	0.0123
30ppm	Dail Reading	6.7	7.1	7.6	8.3	18	26.2	34	35.2	49.8	52.8
	Shear stress	0.2209	0.2561	0.3002	0.3618	1.2164	1.9388	2.626	2.7317	4.018	4.2823
	LN(shear stress)	-1.51	-1.362	-1.203	-1.017	0.1959	0.6621	0.9655	1.0049	1.3908	1.4545
	shear rate	1.5975	3.195	5.3251	10.65	53.251	106.5	159.75	177.5	319.5	355
	Vicosity	0.1383	0.0802	0.0564	0.034	0.0228	0.0182	0.0164	0.0154	0.0126	0.0121

50ppm	Dail Reading	6. 7	7. 6	7. 5	8. 7	17. 3	24. 8	31. 9	33. 1	47	48. 9
	Shear stress	0. 2209	0. 3002	0. 2914	0. 3971	1. 1547	1. 8155	2. 441	2. 5467	3. 7713	3. 9387
	LN(shear stress)	-1. 51	-1. 203	-1. 233	-0. 924	0. 1439	0. 5963	0. 8924	0. 9348	1. 3274	1. 3708
	shear rate	1. 6066	3. 2133	5. 3555	10. 711	53. 555	107. 11	160. 66	178. 52	321. 33	357. 03
	Vicosity	0. 1375	0. 0934	0. 0544	0. 0371	0. 0216	0. 0169	0. 0152	0. 0143	0. 0117	0. 011
70ppm	Dail Reading	6. 4	7	7. 1	8. 3	16. 5	24. 3	31. 1	32	45. 5	47. 9
	Shear stress	0. 1944	0. 2473	0. 2561	0. 3618	1. 0843	1. 7714	2. 3705	2. 4498	3. 6392	3. 8506
	LN(shear stress)	-1. 638	-1. 397	-1. 362	-1. 017	0. 0809	0. 5718	0. 8631	0. 896	1. 2918	1. 3482
	shear rate	1. 599	3. 1979	5. 3298	10. 66	53. 298	106. 6	159. 9	177. 66	319. 79	355. 32
	Vicosity	0. 1216	0. 0773	0. 0481	0. 0339	0. 0203	0. 0166	0. 0148	0. 0138	0. 0114	0. 0108
100ppm	Dail Reading	6. 2	6. 7	6. 9	8. 6	16. 3	24	30. 7	31. 8	44. 9	47. 7
	Shear stress	0. 1768	0. 2209	0. 2385	0. 3883	1. 0666	1. 745	2. 3353	2. 4322	3. 5863	3. 833
	LN(shear stress)	-1. 733	-1. 51	-1. 433	-0. 946	0. 0645	0. 5568	0. 8481	0. 8888	1. 2771	1. 3436
	shear rate	1. 5957	3. 1914	5. 319	10. 638	53. 19	106. 38	159. 57	177. 3	319. 14	354. 6
	Vicosity	0. 1108	0. 0692	0. 0448	0. 0365	0. 0201	0. 0164	0. 0146	0. 0137	0. 0112	0. 0108
120ppm	Dail Reading	5. 7	5. 8	6. 5	7. 7	16. 2	24. 9	30. 9	31. 9	44. 7	47. 4
	Shear stress	0. 1328	0. 1416	0. 2033	0. 309	1. 0578	1. 8243	2. 3529	2. 441	3. 5687	3. 8065
	LN(shear stress)	-2. 019	-1. 955	-1. 593	-1. 175	0. 0562	0. 6012	0. 8556	0. 8924	1. 2722	1. 3367
	shear rate	1. 5783	3. 1566	5. 2609	10. 522	52. 609	105. 22	157. 83	175. 36	315. 66	350. 73
	Vicosity	0. 0841	0. 0449	0. 0386	0. 0294	0. 0201	0. 0173	0. 0149	0. 0139	0. 0113	0. 0109
150ppm	Dail Reading	5. 5	6. 2	6. 3	7. 8	16. 6	23. 7	30	30. 7	44. 1	46. 8
	Shear stress	0. 1152	0. 1768	0. 1856	0. 3178	1. 0931	1. 7186	2. 2736	2. 3353	3. 5158	3. 7537
	LN(shear stress)	-2. 162	-1. 733	-1. 684	-1. 146	0. 089	0. 5415	0. 8214	0. 8481	1. 2573	1. 3227
	shear rate	1. 5799	3. 1597	5. 2662	10. 532	52. 662	105. 32	157. 99	175. 54	315. 97	351. 08
	Vicosity	0. 0729	0. 056	0. 0352	0. 0302	0. 0208	0. 0163	0. 0144	0. 0133	0. 0111	0. 0107
200ppm	Dail Reading	5. 2	5. 8	6. 1	7. 6	16	23. 5	30	31. 2	44	46. 6
	Shear stress	0. 0887	0. 1416	0. 168	0. 3002	1. 0402	1. 701	2. 2736	2. 3793	3. 507	3. 7361
	LN(shear stress)	-2. 422	-1. 955	-1. 784	-1. 203	0. 0394	0. 5312	0. 8214	0. 8668	1. 2548	1. 318
	shear rate	1. 5711	3. 1422	5. 237	10. 474	52. 37	104. 74	157. 11	174. 57	314. 22	349. 13
	Vicosity	0. 0565	0. 0451	0. 0321	0. 0287	0. 0199	0. 0162	0. 0145	0. 0136	0. 0112	0. 0107

Flow Data

100ppm CMC with 20ppm Amphosol in 1inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.01	1	2	1.031	0.02214	0.058295	152.5798	0.023885	0.995798	0.587352	2.22066E-05
1.127	1	2	1.129	0.201618	0.530862	2716.515	0.035851	1.494666	0.010631	0.000202225
1.194	1	2	1.365	0.304396	0.801477	4647.515	0.064667	2.696023	0.008413	0.000305312
1.266	1	2	1.589	0.414844	1.092288	6957.785	0.092017	3.836293	0.006445	0.000416092
1.341	1	2	1.904	0.529894	1.395215	9572.79	0.130478	5.439799	0.005601	0.000531488
1.405	1	2	2.3	0.62807	1.653713	11947.08	0.17883	7.455634	0.005465	0.00062996
1.506	1	2	2.908	0.783004	2.061656	15925	0.253067	10.55065	0.004975	0.00078536
1.579	1	2	3.397	0.894986	2.356505	18956.17	0.312774	13.03991	0.004707	0.000897679
1.703	1	2	4.251	1.085202	2.857346	24369.48	0.417047	17.38719	0.004269	0.001088467
1.804	1	3	1.412	1.240136	3.265288	28999.83	0.494137	20.60116	0.003873	0.001243868
1.865	1	3	1.471	1.33371	3.511669	31884.21	0.568365	23.69581	0.003852	0.001337723
1.907	1	3	1.511	1.398138	3.681309	33906.47	0.618689	25.79388	0.003815	0.001402345
1.945	1	3	1.551	1.45643	3.834792	35760.71	0.669013	27.89195	0.003802	0.001460812
2.205	1	3	1.631	1.85527	4.884941	49026.04	0.769661	32.08808	0.002695	0.001860853
2.229	1	3	1.87	1.892086	4.981878	50297.99	1.070347	44.62403	0.003604	0.001897779
2.458	1	3	2.163	2.243372	5.906817	62799.76	1.43897	59.99238	0.003446	0.002250122
2.713	1	3	2.568	2.634542	6.936771	77436.78	1.948501	81.23531	0.003384	0.002642469
2.992	1	3	3.019	3.062528	8.063661	94224.43	2.515904	104.891	0.003233	0.003071743
3.316	1	3	3.648	3.559544	9.372309	114630.6	3.307249	137.8831	0.003146	0.003570255
3.46	1	3	3.941	3.78044	9.95393	123989.4	3.675872	153.2515	0.0031	0.003791815
3.589	1	3	4.201	3.978326	10.47497	132515.8	4.002978	166.8889	0.003049	0.003990297
3.761	1	3	4.578	4.242174	11.16968	144085.3	4.477282	186.6632	0.002999	0.004254939

100ppm CMC with 20ppm Amphosol in 1.5inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.048	2	2	1.007	0.080432	0.084792	342.0188	0.020955	0.412387	0.114968	8.0674E-05
1.1	2	2	1.044	0.1602	0.168885	839.6554	0.025472	0.501295	0.035229	0.00016068
1.264	2	2	1.261	0.411776	0.4341	2874.314	0.051968	1.022728	0.010878	0.00041302
1.393	2	2	1.46	0.609662	0.642714	4793.88	0.076266	1.500909	0.007283	0.0006115
1.535	2	2	1.779	0.82749	0.872351	7138.833	0.115216	2.26744	0.005972	0.00082998
1.7	2	2	2.263	1.0806	1.139183	10108.94	0.174312	3.430453	0.005298	0.00108385
1.832	2	2	2.695	1.283088	1.352648	12645.49	0.22706	4.468514	0.004895	0.00128695
1.985	2	2	3.279	1.51779	1.600074	15741.02	0.298366	5.871819	0.004597	0.00152236
2.12	2	2	3.86	1.72488	1.818391	18596.82	0.369306	7.267914	0.004406	0.00173007
2.289	2	2	4.623	1.984126	2.091691	22320.56	0.462468	9.101342	0.00417	0.0019901
2.366	2	3	1.403	2.102244	2.216213	24068.05	0.482814	9.501749	0.003878	0.00210857
2.431	2	3	1.433	2.201954	2.321328	25566.66	0.520557	10.24453	0.003811	0.00220858
2.479	2	3	1.452	2.275586	2.398952	26686.68	0.544461	10.71496	0.003732	0.00228243
2.77	2	3	1.623	2.72198	2.869547	33705.13	0.759596	14.9488	0.003639	0.00273017
3.209	2	3	1.907	3.395406	3.579481	44961.51	1.116897	21.98044	0.003439	0.00340562
3.466	2	3	2.107	3.789644	3.995092	51883.17	1.368517	26.93231	0.003382	0.00380105
3.863	2	3	2.427	4.398642	4.637105	63007.07	1.771109	34.85529	0.003249	0.00441188
4.327	2	3	2.833	5.110418	5.387469	76611.94	2.281897	44.90757	0.003101	0.0051258
4.718	2	3	3.216	5.710212	6.01978	88535.96	2.76375	54.39039	0.003008	0.00572739
4.906	2	3	3.415	5.998604	6.323806	94408.68	3.014112	59.31749	0.002973	0.00601665
5.087	2	3	3.593	6.276258	6.616513	100144.4	3.238053	63.72465	0.002918	0.00629514

100ppm CMC with 100ppm Amphosol in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.071	1	2	1.058	0.115714	0.305104	1718.982	0.027182	1.133241	0.024436	0.000116
1.108	1	2	1.141	0.172472	0.454758	2772.17	0.037316	1.555752	0.0151	0.000173
1.183	1	2	1.298	0.287522	0.758111	5111.94	0.056486	2.35496	0.008225	0.000288
1.296	1	2	1.705	0.460864	1.215164	8993.631	0.106181	4.426791	0.006017	0.000462
1.413	1	2	2.314	0.640342	1.688395	13334.32	0.180539	7.526901	0.0053	0.000642
1.514	1	2	2.914	0.795276	2.09691	17284.35	0.253799	10.5812	0.00483	0.000798
1.59	1	2	3.45	0.91186	2.404308	20360.62	0.319245	13.3097	0.004622	0.000915
1.725	1	2	4.563	1.11895	2.950344	26014.71	0.455142	18.97542	0.004376	0.001122
1.827	1	3	1.452	1.275418	3.362905	30428.56	0.544461	22.69923	0.004029	0.001279
1.88	1	3	1.504	1.35672	3.577274	32765.5	0.609882	25.42672	0.003988	0.001361
1.965	1	3	1.599	1.48711	3.921074	36570.98	0.729402	30.40963	0.00397	0.001492
2.007	1	3	1.639	1.551538	4.090952	38476.18	0.779726	32.5077	0.003899	0.001556
2.166	1	3	1.827	1.795444	4.734061	45826.68	1.016249	42.36861	0.003795	0.001801
2.298	1	3	2.009	1.997932	5.267963	52082.08	1.245223	51.91482	0.003755	0.002004
2.444	1	3	2.211	2.221896	5.85849	59147.99	1.499359	62.51006	0.003656	0.002229
2.659	1	3	2.556	2.551706	6.728103	69809.1	1.933404	80.60588	0.003574	0.002559
2.976	1	3	3.111	3.037984	8.010276	86024.25	2.631649	109.7166	0.003432	0.003047
3.259	1	3	3.666	3.472106	9.154929	100943.7	3.329895	138.8272	0.003325	0.003483
3.421	1	3	4.014	3.720614	9.810172	109654.6	3.767713	157.0804	0.003276	0.003732
3.571	1	3	4.352	3.950714	10.41688	117823.6	4.192951	174.8091	0.003234	0.003963
3.666	1	3	4.567	4.096444	10.80113	123046.5	4.463443	186.0862	0.003202	0.004109
3.718	1	3	4.703	4.176212	11.01145	125921	4.634544	193.2196	0.003199	0.004189

100ppm CMC with 100ppm Amphosol in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in Vol
1.046	2	3	1.021	0.077364	0.081673	543.9655	0.022664	0.446028	0.134216	7.75968E-05
1.127	2	2	1.074	0.201618	0.212847	1712.688	0.029135	0.573382	0.025404	0.000202225
1.216	2	2	1.159	0.338144	0.356977	3181.128	0.039514	0.777631	0.012249	0.000339161
1.332	2	2	1.351	0.516088	0.544831	5277.768	0.062957	1.238991	0.008378	0.000517641
1.433	2	2	1.533	0.671022	0.708394	7227.19	0.085179	1.676322	0.006705	0.000673041
1.614	2	2	1.99	0.948676	1.001512	10940.47	0.140979	2.774456	0.005552	0.000951531
1.69	2	2	2.221	1.06526	1.124589	12569.27	0.169184	3.32953	0.005284	0.001068465
1.905	2	2	2.981	1.39507	1.472767	17360.97	0.26198	5.155749	0.004771	0.001399268
2.108	2	2	3.826	1.706472	1.801513	22097.87	0.365155	7.186215	0.004444	0.001711607
2.238	2	2	4.379	1.905892	2.012039	25224.61	0.432676	8.515029	0.004222	0.001911627
2.302	2	2	4.693	2.004068	2.115683	26788.28	0.471015	9.269546	0.004157	0.002010098
2.358	2	3	1.395	2.089972	2.206371	28168.98	0.47275	9.303675	0.003836	0.002096261
2.41	2	3	1.429	2.16974	2.290582	29461.13	0.515525	10.14549	0.003881	0.002176269
2.474	2	3	1.46	2.267916	2.394226	31064.37	0.554526	10.91303	0.003821	0.00227474
2.67	2	3	1.571	2.56858	2.711635	36057.98	0.694175	13.66131	0.003729	0.002576309
2.832	2	3	1.674	2.817088	2.973983	40274.1	0.823759	16.21152	0.003679	0.002825565
3.084	2	3	1.841	3.203656	3.382081	46978.08	1.033862	20.34633	0.00357	0.003213296
3.258	2	3	1.97	3.470572	3.663863	51702.44	1.196157	23.54028	0.00352	0.003481015
3.5	2	3	2.155	3.8418	4.055766	58392.46	1.428906	28.12075	0.003431	0.00385336
3.719	2	3	2.355	4.177746	4.410422	64558.12	1.680526	33.07262	0.003413	0.004190317
4.142	2	3	2.751	4.826628	5.095443	76741.44	2.178733	42.8773	0.003315	0.004841151
4.549	2	3	3.147	5.450966	5.754553	88774.49	2.676941	52.68199	0.003193	0.005467368
4.79	2	3	3.391	5.82066	6.144837	96031.25	2.983917	58.72327	0.003122	0.005838175
4.932	2	3	3.564	6.038488	6.374797	100350.2	3.201568	63.00663	0.003112	0.006056658
5.06	2	3	3.688	6.23484	6.582084	104269.8	3.357573	66.07678	0.003061	0.006253601

100ppm CMC with 300ppm Amphosol in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.06	1	3	1.034	0.09884	0.260508	1521.481	0.024251	1.01107	0.029892	9.91374E-05
1.104	1	2	1.12	0.166336	0.438403	3035.407	0.034752	1.448852	0.015125	0.000166837
1.174	1	2	1.301	0.273716	0.721419	5878.194	0.056852	2.370231	0.009138	0.00027454
1.241	1	2	1.522	0.376494	0.992306	8973.537	0.083836	3.49523	0.007122	0.000377627
1.381	1	2	1.832	0.591254	1.558338	16332.67	0.121687	5.073283	0.004192	0.000593033
1.417	1	2	2.257	0.646478	1.70389	18387.13	0.17358	7.236743	0.005001	0.000648423
1.518	1	2	2.954	0.801412	2.112241	24452.12	0.258683	10.78482	0.00485	0.000803823
1.631	1	2	3.792	0.974754	2.56911	31707	0.361003	15.05065	0.004575	0.000977687
1.736	1	2	4.644	1.135824	2.993634	38840.29	0.465032	19.38775	0.004341	0.001139242
1.772	1	3	1.406	1.191048	3.139185	41365.74	0.486589	20.28645	0.00413	0.001194632
1.809	1	3	1.44	1.247806	3.288779	44001.53	0.529364	22.06981	0.004094	0.001251561
1.942	1	3	1.576	1.451828	3.82651	53794.21	0.700466	29.20324	0.004002	0.001456197
2.041	1	3	1.695	1.603694	4.226776	61385.53	0.85018	35.44499	0.003981	0.00160852
2.25	1	3	1.969	1.9243	5.071781	78179.31	1.194899	49.81675	0.003886	0.00193009
2.483	1	3	2.319	2.281722	6.01382	98009.71	1.635234	68.17484	0.003782	0.002288588
2.736	1	3	2.752	2.669824	7.036721	120723	2.179991	90.88641	0.003683	0.002677858
3.008	1	3	3.259	3.087072	8.13644	146376	2.817848	117.4794	0.003561	0.003096361
3.259	1	3	3.779	3.472106	9.151255	171081.5	3.47206	144.7543	0.003468	0.003482554
3.391	1	3	4.047	3.674594	9.684942	184444.9	3.809231	158.8113	0.003397	0.003685651
3.495	1	3	4.289	3.83413	10.10542	195145.2	4.113691	171.5046	0.00337	0.003845667
3.607	1	3	4.546	4.005938	10.55825	206832.4	4.437023	184.9847	0.003329	0.004017992

100ppm CMC with 300ppm Amphosol in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.038	2	2	1.015	0.065092	0.06869	359.0976	0.021932	0.43161	0.18354	6.52879E-05
1.142	2	2	1.091	0.224628	0.237043	1857.805	0.031211	0.614232	0.021933	0.000225304
1.28	2	2	1.27	0.43632	0.460436	4483.325	0.053067	1.044355	0.009884	0.000437633
1.378	2	2	1.434	0.586652	0.619077	6640.594	0.073091	1.438433	0.00753	0.000588417
1.54	2	2	1.808	0.83516	0.88132	10610.58	0.118757	2.337125	0.006037	0.000837673
1.706	2	2	2.269	1.089804	1.150038	15104.29	0.175045	3.444871	0.005226	0.001093083
1.863	2	2	2.803	1.330642	1.404187	19686.1	0.240246	4.728029	0.004811	0.001334646
1.905	2	2	2.979	1.39507	1.472176	20960.77	0.261736	5.150943	0.004769	0.001399268
1.96	2	2	3.175	1.47944	1.561209	22659.22	0.285668	5.621915	0.004628	0.001483892
2.145	2	2	3.966	1.76323	1.860685	28600.27	0.382249	7.522624	0.00436	0.001768536
2.22	2	2	4.322	1.87828	1.982094	31102.5	0.425716	8.378063	0.004279	0.001883932
2.414	2	3	1.434	2.175876	2.296138	37805.02	0.521815	10.26929	0.003908	0.002182423
2.582	2	3	1.529	2.433588	2.568094	43858.52	0.641335	12.62142	0.00384	0.002440911
2.77	2	3	1.658	2.72198	2.872425	50885.21	0.80363	15.81537	0.003846	0.002730171
2.956	2	3	1.775	3.007304	3.173519	58081.29	0.950828	18.71221	0.003728	0.003016353
3.209	2	3	1.961	3.395406	3.583072	68231.19	1.184834	23.31745	0.003644	0.003405623
3.388	2	3	2.103	3.669992	3.872835	75647.91	1.363484	26.83327	0.00359	0.003681035
3.682	2	3	2.358	4.120988	4.348757	88224.27	1.6843	33.14689	0.003517	0.004133388
3.938	2	3	2.584	4.513692	4.763166	99549.98	1.96863	38.7425	0.003426	0.004527274
4.171	2	3	2.783	4.871114	5.140343	110143	2.218992	43.6696	0.003316	0.004885771
4.43	2	3	3.059	5.26842	5.559609	122219.5	2.566228	50.50317	0.003278	0.005284273
4.704	2	3	3.4	5.688736	6.003156	135323.5	2.99524	58.9461	0.003282	0.005705854
4.865	2	3	3.519	5.93571	6.26378	143173.8	3.144954	61.89246	0.003165	0.005953571

500ppm CMC with 100ppm Amphosol in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.082	1	2	1.35	0.132588	0.349315	558.9501	0.062835	2.619666	0.043058	0.000133
1.166	1	2	1.446	0.261444	0.688798	1439.826	0.074557	3.108353	0.01314	0.000262
1.251	1	2	1.585	0.391834	1.032323	2530.453	0.091529	3.815932	0.007182	0.000393
1.34	1	2	1.941	0.52836	1.392013	3838.188	0.134996	5.628147	0.005825	0.00053
1.405	1	2	2.214	0.62807	1.654708	4883.769	0.168329	7.017852	0.005141	0.00063
1.505	1	2	2.734	0.78147	2.058855	6622.374	0.231821	9.664909	0.004573	0.000784
1.613	1	2	3.422	0.947142	2.495333	8657.315	0.315826	13.16717	0.004241	0.00095
1.755	1	2	4.341	1.16497	3.069221	11552.27	0.428036	17.84533	0.003799	0.001168
1.9	1	3	1.448	1.3874	3.655234	14737.49	0.539429	22.48943	0.003376	0.001392
1.995	1	3	1.521	1.53313	4.039173	16938.46	0.63127	26.3184	0.003235	0.001538
2.19	1	3	1.697	1.83226	4.827258	21714.51	0.852696	35.54989	0.00306	0.001838
2.317	1	3	1.829	2.027078	5.340524	24998.03	1.018765	42.47351	0.002987	0.002033
2.541	1	3	2.076	2.370694	6.245813	31094.07	1.329516	55.42908	0.00285	0.002378
2.726	1	3	2.298	2.654484	6.993484	36400.71	1.608814	67.07335	0.00275	0.002662
3.064	1	3	2.751	3.172976	8.359499	46676.17	2.178733	90.83396	0.002607	0.003183
3.136	1	3	2.853	3.283424	8.650484	48955.83	2.307059	96.18403	0.002578	0.003293
3.472	1	3	3.377	3.798848	10.00842	59986.57	2.966304	123.6687	0.002476	0.00381
3.514	1	3	3.429	3.863276	10.17816	61409.09	3.031725	126.3962	0.002447	0.003875
3.611	1	3	3.584	4.012074	10.57018	64730.07	3.22673	134.5262	0.002415	0.004024
3.724	1	3	3.792	4.185416	11.02687	68660.36	3.488415	145.4362	0.002399	0.004198
3.905	1	3	4.077	4.46307	11.75837	75089.75	3.846974	160.3849	0.002327	0.004476

500ppm CMC with 100ppm Amphosol in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.115	2	2	1.081	0.18321	0.193259	323.3234	0.02999	0.590203	0.031694	0.000184
1.174	2	2	1.11	0.273716	0.288729	565.7345	0.033531	0.659888	0.015876	0.000275
1.307	2	2	1.429	0.477738	0.503941	1229.448	0.072481	1.426419	0.011265	0.000479
1.386	2	2	1.574	0.598924	0.631773	1684.753	0.090185	1.774842	0.008918	0.000601
1.468	2	2	1.8	0.724712	0.76446	2197.443	0.11778	2.317902	0.007955	0.000727
1.578	2	2	2.131	0.893452	0.942455	2941.738	0.158195	3.113268	0.00703	0.000896
1.671	2	2	2.428	1.036114	1.092942	3616.288	0.194459	3.826935	0.006425	0.001039
1.739	2	2	2.695	1.140426	1.202975	4133.518	0.22706	4.468514	0.006193	0.001144
1.95	2	2	3.471	1.4641	1.544402	5855.048	0.321809	6.333179	0.005325	0.001469
2.088	2	2	3.997	1.675792	1.767705	7067.475	0.386034	7.597114	0.004876	0.001681
2.194	2	2	4.479	1.838396	1.939227	8041.062	0.444886	8.755321	0.004669	0.001844
2.325	2	3	1.404	2.03935	2.151203	9291.778	0.484072	9.526509	0.004129	0.002045
2.484	2	3	1.483	2.283256	2.408486	10876.09	0.583462	11.48249	0.00397	0.00229
2.642	2	3	1.558	2.525628	2.664152	12517.95	0.67782	13.33944	0.003769	0.002533
2.738	2	3	1.598	2.672892	2.819493	13546.67	0.728144	14.32982	0.003615	0.002681
2.841	2	3	1.646	2.830894	2.986161	14675.46	0.788533	15.51826	0.00349	0.002839
3.078	2	3	1.773	3.194452	3.369659	17366.72	0.948311	18.6627	0.003296	0.003204
3.225	2	3	1.85	3.41995	3.607525	19098.58	1.045185	20.56916	0.00317	0.00343
3.551	2	3	2.018	3.920034	4.135037	23099.35	1.256546	24.72873	0.002901	0.003932
3.836	2	3	2.208	4.357224	4.596206	26766.65	1.495585	29.433	0.002794	0.00437
4.125	2	3	2.343	4.80055	5.063847	30636.44	1.665428	32.7755	0.002564	0.004815
4.577	2	3	2.628	5.493918	5.795244	36973.53	2.023987	39.83191	0.002379	0.00551
4.747	2	3	2.712	5.754698	6.070328	39441.96	2.129667	41.91169	0.002281	0.005772
4.896	2	3	2.758	5.983264	6.31143	41642.05	2.18754	43.05062	0.002168	0.006001
5.121	2	3	2.959	6.328414	6.67551	45027.27	2.440418	48.02724	0.002162	0.006347

500ppm CMC with 100ppm Amphosol in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.082	1	2	1.35	0.132588	0.349315	558.9501	0.062835	2.619666	0.043058	0.000133
1.166	1	2	1.446	0.261444	0.688798	1439.826	0.074557	3.108353	0.01314	0.000262
1.251	1	2	1.585	0.391834	1.032323	2530.453	0.091529	3.815932	0.007182	0.000393
1.34	1	2	1.941	0.52836	1.392013	3838.188	0.134996	5.628147	0.005825	0.00053
1.405	1	2	2.214	0.62807	1.654708	4883.769	0.168329	7.017852	0.005141	0.00063
1.505	1	2	2.734	0.78147	2.058855	6622.374	0.231821	9.664909	0.004573	0.000784
1.613	1	2	3.422	0.947142	2.495333	8657.315	0.315826	13.16717	0.004241	0.00095
1.755	1	2	4.341	1.16497	3.069221	11552.27	0.428036	17.84533	0.003799	0.001168
1.9	1	3	1.448	1.3874	3.655234	14737.49	0.539429	22.48943	0.003376	0.001392
1.995	1	3	1.521	1.53313	4.039173	16938.46	0.63127	26.3184	0.003235	0.001538
2.19	1	3	1.697	1.83226	4.827258	21714.51	0.852696	35.54989	0.00306	0.001838
2.317	1	3	1.829	2.027078	5.340524	24998.03	1.018765	42.47351	0.002987	0.002033
2.541	1	3	2.076	2.370694	6.245813	31094.07	1.329516	55.42908	0.00285	0.002378
2.726	1	3	2.298	2.654484	6.993484	36400.71	1.608814	67.07335	0.00275	0.002662
3.064	1	3	2.751	3.172976	8.359499	46676.17	2.178733	90.83396	0.002607	0.003183
3.136	1	3	2.853	3.283424	8.650484	48955.83	2.307059	96.18403	0.002578	0.003293
3.472	1	3	3.377	3.798848	10.00842	59986.57	2.966304	123.6687	0.002476	0.00381
3.514	1	3	3.429	3.863276	10.17816	61409.09	3.031725	126.3962	0.002447	0.003875
3.611	1	3	3.584	4.012074	10.57018	64730.07	3.22673	134.5262	0.002415	0.004024
3.724	1	3	3.792	4.185416	11.02687	68660.36	3.488415	145.4362	0.002399	0.004198
3.905	1	3	4.077	4.46307	11.75837	75089.75	3.846974	160.3849	0.002327	0.004476

500ppm CMC with 300ppm Amphosol in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.076	1	2	1.045	0.123384	0.324904	613.8838	0.025595	1.067065	0.020263	0.000124
1.16	1	2	1.302	0.25224	0.664217	1640.379	0.056974	2.375322	0.010793	0.000253
1.233	1	2	1.518	0.364222	0.959096	2717.995	0.083348	3.474868	0.007573	0.000365
1.312	1	2	1.851	0.485408	1.278211	4033.712	0.124007	5.170003	0.006343	0.000487
1.432	1	2	2.482	0.669488	1.762944	6275.298	0.201052	8.382104	0.005406	0.000672
1.549	1	2	3.17	0.848966	2.235559	8697.824	0.285057	11.88436	0.004767	0.000852
1.642	1	2	3.823	0.991628	2.611226	10767.93	0.364788	15.20846	0.004471	0.000995
1.738	1	2	4.532	1.138892	2.999013	13025.25	0.451357	18.81762	0.004194	0.001142
1.843	1	3	1.441	1.299962	3.423154	15622.43	0.530622	22.12226	0.003784	0.001304
1.912	1	3	1.5	1.405808	3.701875	17397.03	0.60485	25.21691	0.003689	0.00141
1.972	1	3	1.557	1.497848	3.944241	18981.53	0.676562	28.20666	0.003635	0.001502
2.015	1	3	1.599	1.56381	4.117937	20139.88	0.729402	30.40963	0.003595	0.001569
2.169	1	3	1.754	1.800046	4.740011	24436.46	0.924407	38.53964	0.003439	0.001805
2.285	1	3	1.881	1.97799	5.208586	27817.04	1.084186	45.201	0.00334	0.001984
2.471	1	3	2.107	2.263314	5.959922	33477.09	1.368517	57.05508	0.00322	0.00227
2.674	1	3	2.368	2.574716	6.779928	39966.71	1.696881	70.74497	0.003085	0.002582
2.865	1	3	2.628	2.86771	7.551461	46348.22	2.023987	84.38241	0.002966	0.002876
3.054	1	3	2.919	3.157636	8.314915	52908.33	2.390094	99.64584	0.002889	0.003167
3.278	1	3	3.28	3.501252	9.219749	60979.79	2.844268	118.5809	0.002796	0.003512
3.453	1	3	3.569	3.769702	9.926651	67497.07	3.207859	133.7394	0.002721	0.003781
3.529	1	3	3.719	3.886286	10.23365	70382.78	3.396574	141.6072	0.002711	0.003898
3.633	1	3	3.903	4.045822	10.65375	74384.38	3.628064	151.2583	0.002671	0.004058
3.744	1	3	4.114	4.216096	11.10213	78720.96	3.893523	162.3256	0.00264	0.004229
3.855	1	3	4.333	4.38637	11.55051	83123.65	4.169047	173.8125	0.002612	0.0044

500ppm CMC with 300ppm Amphosol in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.027	2	2	0.992	0.048218	0.050883	63.92779	0.019123	0.376343	0.291649	4.83631E-05
1.102	2	2	1.079	0.163268	0.172292	341.7836	0.029746	0.585397	0.039568	0.000163759
1.205	2	2	1.152	0.32127	0.339027	866.5861	0.038659	0.76081	0.013281	0.000322237
1.274	2	2	1.279	0.427116	0.450723	1281.752	0.054166	1.065981	0.010528	0.000428401
1.374	2	2	1.48	0.580516	0.612601	1954.255	0.078708	1.548968	0.008281	0.000582263
1.488	2	2	1.747	0.755392	0.797143	2806.51	0.111309	2.190547	0.006917	0.000757665
1.584	2	2	2.013	0.902656	0.952546	3584.958	0.143787	2.829723	0.006257	0.000905372
1.658	2	2	2.242	1.016172	1.072336	4218.86	0.171748	3.379992	0.005898	0.00101923
1.755	2	2	2.559	1.16497	1.229359	5090.592	0.210454	4.141717	0.005499	0.001168475
1.871	2	2	2.99	1.342914	1.417138	6189.006	0.263079	5.177375	0.005173	0.001346955
2.004	2	2	3.54	1.546936	1.632436	7517.067	0.330234	6.49898	0.004893	0.001551591
2.093	2	2	3.91	1.683462	1.776508	8443.746	0.375411	7.38806	0.004697	0.001688528
2.184	2	2	4.298	1.823056	1.923817	9420.811	0.422786	8.320393	0.004511	0.001828542
2.244	2	2	4.592	1.915096	2.020944	10080.67	0.458683	9.026851	0.004435	0.001920859
2.295	2	2	4.847	1.99333	2.103502	10651	0.489819	9.639595	0.004371	0.001999328
2.423	2	3	1.453	2.189682	2.310707	12119.16	0.545719	10.73972	0.004036	0.002196271
2.472	2	3	1.475	2.264848	2.390027	12694.62	0.573398	11.28442	0.003964	0.002271663
2.703	2	3	1.606	2.619202	2.763967	15502.15	0.738209	14.52789	0.003816	0.002627083
2.883	2	3	1.711	2.895322	3.055348	17791.85	0.870309	17.12762	0.003681	0.002904034
3.002	2	3	1.788	3.077868	3.247984	19351.66	0.967183	19.03409	0.00362	0.003087129
3.158	2	3	1.887	3.317172	3.500514	21449.36	1.091735	21.48526	0.003518	0.003327153
3.371	2	3	2.031	3.643914	3.845315	24405.86	1.272901	25.0506	0.003399	0.003654879
3.649	2	3	2.232	4.070366	4.295337	28415.8	1.525779	30.02722	0.003265	0.004082614
3.908	2	3	2.434	4.467672	4.714603	32296.5	1.779915	35.0286	0.003162	0.004481115
4.24	2	3	2.676	4.97696	5.252039	37462.43	2.084376	41.02036	0.002984	0.004991936
4.573	2	3	2.958	5.487782	5.791095	42846.92	2.43916	48.00248	0.002872	0.005504295
4.792	2	3	3.111	5.823728	6.145609	46493	2.631649	51.79066	0.002751	0.005841252
4.889	2	3	3.264	5.972526	6.302631	48133.55	2.824138	55.57883	0.002807	0.005990497
5.052	2	3	3.441	6.222568	6.566493	50924.87	3.046822	59.96123	0.00279	0.006241292
5.121	2	3	3.52	6.328414	6.678189	52119.29	3.146212	61.91722	0.002786	0.006347456

2. Polymer-polymer Studies

Bench-scale

Total 500ppm		(A+B)	A=PEO	B=PAM					
PEO fraction	100%	90%	80%	60%	50%	40%	20%	10%	0%
Concentration	500A	450A+50B	400A+100I	300A+200I	250A+250I	200A+300I	100A+400I	50A+450B	500B
Surface tension	62	62	62.5	62.3	62.5	62.9	63.1	62	71.8
	61.8	61.7	62.6	62.1	62.6	62.8	63.3	62.5	71.9
Avg.	61.9	61.85	62.55	62.2	62.55	62.85	63.2	62.25	71.85
Coductivity	0.029	0.083	0.144	0.275	0.301	0.37	0.53	0.585	0.661
	0.03	0.082	0.146	0.274	0.318	0.368	0.528	0.577	0.662
Avg.	0.0295	0.0825	0.145	0.2745	0.3095	0.369	0.529	0.581	0.6615

Total 1000ppm		(A+B)	A=PEO	B=PAM					
PEO fraction	100%	90%	80%	60%	50%	40%	20%	10%	0%
Concentration	1000A	900A+100B	800A+200B	600A+400B	500A+500B	400A+600B	200A+800B	100A+900B	1000B
Surface tension	62.5	62.1	62.1	62.5	62.2	62.2	62.5	61.5	71.1
	62.3	62.1	62.1	62.7	61.8	62.3	62.3	61.1	70.2
Avg.	62.4	62.1	62.1	62.6	62	62.25	62.4	61.3	70.65
Coductivity	0.058	0.146	0.277	0.512	0.591	0.718	0.942	1.031	1.184
	0.057	0.144	0.276	0.513	0.588	0.72	0.945	1.027	1.184
Avg.	0.0575	0.145	0.2765	0.5125	0.5895	0.719	0.9435	1.029	1.184

Surface tension									
Total 500ppm	ASDA method								
PEO percentage	0%	10%	20%	40%	50%	60%	80%	90%	100%
Surface tension	72.632	62.033	62.286	62.817	63.01	62.818	63.227	63.102	64.015
	72.676	62.099	62.358	62.572	62.824	62.762	62.12	63.074	63.895
	72.5	62.179	62.509	62.826	62.735	62.769	63.29	63.067	63.997
Avg.	72.60267	62.10367	62.38433	62.73833	62.85633	62.783	62.879	63.081	63.969
Total 1000ppm	ASDA method								
PEO percentage	0%	10%	20%	40%	50%	60%	80%	90%	100%
Surface tension	68.427	61.133	61.784	61.546	62.551	62.897	62.702	61.674	61.498
	68.334	61.181	61.927	61.599	62.643	62.78	62.651	61.553	61.701
	68.449	61.325	61.976	61.579	62.613	62.768	62.404	61.635	61.945
Avg.	68.40333	61.213	61.89567	61.57467	62.60233	62.815	62.58567	61.62067	61.71467

Total 500ppm	RPM	30	60	90	100	180	200
500ppm A	Dail Reading	7.1	8.6	9.8	10.6	13.2	14.8
	Shear stress	0.25611	0.38826	0.49398	0.56446	0.79352	0.93448
	LN(shear stress)	-1.36215	-0.94608	-0.70526	-0.57189	-0.23128	-0.06777
	shear rate	52.47842	104.9568	157.4353	174.9281	314.8705	349.8561
	Vicosity	0.00488	0.003699	0.003138	0.003227	0.00252	0.002671
450A+50B	Dail Reading	8.6	11	12.8	14	18.4	19
	Shear stress	0.38826	0.5997	0.75828	0.864	1.25164	1.3045
	LN(shear stress)	-0.94608	-0.51133	-0.2767	-0.14618	0.224455	0.26582
	shear rate	52.83758	105.6752	158.5127	176.1253	317.0255	352.2505
	Vicosity	0.007348	0.005675	0.004784	0.004906	0.003948	0.003703
400A+100B	Dail Reading	10.8	12.5	14.8	15.4	20.2	21.3
	Shear stress	0.58208	0.73185	0.93448	0.98734	1.41022	1.50713
	LN(shear stress)	-0.54115	-0.31218	-0.06777	-0.01274	0.343746	0.410207
	shear rate	53.64791	107.2958	160.9437	178.8264	321.8875	357.6527
	Vicosity	0.01085	0.006821	0.005806	0.005521	0.004381	0.004214
300A+200B	Dail Reading	13.4	16.5	18.6	19.8	25.4	26.3
	Shear stress	0.81114	1.08425	1.26926	1.37498	1.86834	1.94763
	LN(shear stress)	-0.20931	0.080889	0.238434	0.318439	0.62505	0.666613
	shear rate	54.81542	109.6308	164.4463	182.7181	328.8925	365.4362
	Vicosity	0.014798	0.00989	0.007718	0.007525	0.005681	0.00533
250A+250B	Dail Reading	14.3	18.5	21.1	21.9	27.9	30
	Shear stress	0.89043	1.26045	1.48951	1.55999	2.08859	2.2736
	LN(shear stress)	-0.11605	0.231469	0.398447	0.444679	0.736489	0.821364
	shear rate	54.56873	109.1375	163.7062	181.8958	327.4124	363.7916
	Vicosity	0.016318	0.011549	0.009099	0.008576	0.006379	0.00625
200A+300B	Dail Reading	16.5	20.6	22.8	24.4	31	32.6
	Shear stress	1.08425	1.44546	1.63928	1.78024	2.3617	2.50266
	LN(shear stress)	0.080889	0.368428	0.494257	0.576748	0.859382	0.917354
	shear rate	54.78901	109.578	164.367	182.63	328.734	365.2601
	Vicosity	0.01979	0.013191	0.009973	0.009748	0.007184	0.006852

100A+400B	Dail Reading	18	21.6	25.2	25.9	33.3	34.5
	Shear stress	1.2164	1.53356	1.85072	1.91239	2.56433	2.67005
	LN(shear stress)	0.195896	0.427592	0.615575	0.648354	0.941697	0.982097
	shear rate	55.31817	110.6363	165.9545	184.3939	331.909	368.7878
	Vicosity	0.021989	0.013861	0.011152	0.010371	0.007726	0.00724
50A+450B	Dail Reading	18.8	23.8	27.8	28.4	36.5	38
	Shear stress	1.28688	1.72738	2.07978	2.13264	2.84625	2.9784
	LN(shear stress)	0.252221	0.546606	0.732262	0.757361	1.046002	1.091386
	shear rate	55.18231	110.3646	165.5469	183.941	331.0938	367.882
	Vicosity	0.023321	0.015652	0.012563	0.011594	0.008597	0.008096
500B	Dail Reading	21	24.2	28.7	29.5	38.9	40.6
	Shear stress	1.4807	1.76262	2.15907	2.22955	3.05769	3.20746
	LN(shear stress)	0.392515	0.566801	0.769678	0.8018	1.11766	1.165479
	shear rate	54.92254	109.8451	164.7676	183.0751	329.5353	366.1503
	Vicosity	0.02696	0.016046	0.013104	0.012178	0.009279	0.00876

Total 1000ppm	RPM	30	60	90	100	180	200
1000ppm A	Dail Reading	9	11.1	13.7	14	19.9	20.3
	Shear stress	0.4235	0.60851	0.83757	0.864	1.38379	1.41903
	LN(shear stress)	-0.859202	-0.49674	-0.17725	-0.14618	0.3248261	0.3499735
	shear rate	52.364712	104.7294	157.09414	174.549	314.18827	349.09808
	Vicosity	0.0080875	0.00581	0.0053316	0.00495	0.0044043	0.0040648
900A+100B	Dail Reading	11.8	16	19.1	20.2	26.3	27.8
	Shear stress	0.67018	1.0402	1.31331	1.41022	1.94763	2.07978
	LN(shear stress)	-0.400209	0.039413	0.2725507	0.343746	0.6666132	0.7322621
	shear rate	53.328358	106.6567	159.98507	177.7612	319.97015	355.52238
	Vicosity	0.012567	0.009753	0.008209	0.007933	0.0060869	0.0058499
800A+200B	Dail Reading	15.3	19.8	23.2	25	32.3	34.5
	Shear stress	0.97853	1.37498	1.67452	1.8331	2.47623	2.67005
	LN(shear stress)	-0.021704	0.318439	0.5155266	0.606009	0.9067372	0.9820972
	shear rate	53.328358	106.6567	159.98507	177.7612	319.97015	355.52238
	Vicosity	0.0183491	0.012892	0.0104667	0.010312	0.0077389	0.0075102

600A+400B	Dail Reading	21.4	27.3	32.1	32.9	41.5	44
	Shear stress	1.51594	2.03573	2.45861	2.52909	3.28675	3.507
	LN(shear stress)	0.4160357	0.710854	0.8995961	0.92786	1.1898992	1.254761
	shear rate	55.254696	110.5094	165.76409	184.1823	331.52818	368.36464
	Vicosity	0.0274355	0.018421	0.014832	0.013731	0.0099139	0.0095205
500A+500B	Dail Reading	24.3	28.5	33.2	34.9	45.3	46.8
	Shear stress	1.77143	2.14145	2.55552	2.70529	3.62153	3.75368
	LN(shear stress)	0.5717871	0.761483	0.9382557	0.995209	1.2868966	1.3227367
	shear rate	55.588465	111.1769	166.76539	185.2949	333.53079	370.58976
	Vicosity	0.0318669	0.019262	0.015324	0.0146	0.0108582	0.0101289
400A+600B	Dail Reading	26	32.6	37.2	39.5	50.2	54
	Shear stress	1.9212	2.50266	2.90792	3.11055	4.05322	4.388
	LN(shear stress)	0.65295	0.917354	1.067438	1.1348	1.3995116	1.4788735
	shear rate	54.839102	109.6782	164.51731	182.797	329.03461	365.59401
	Vicosity	0.0350334	0.022818	0.0176755	0.017016	0.0123185	0.0120024
200A+800B	Dail Reading	30.4	37	42	43.1	56.1	59
	Shear stress	2.30884	2.8903	3.3308	3.42771	4.57301	4.8285
	LN(shear stress)	0.8367452	1.06136	1.2032125	1.231892	1.5201716	1.5745359
	shear rate	55.641445	111.2829	166.92434	185.4715	333.84867	370.94297
	Vicosity	0.041495	0.025973	0.019954	0.018481	0.0136979	0.0130168
100A+900B	Dail Reading	31	37.8	44.2	45.5	59.7	62.8
	Shear stress	2.3617	2.96078	3.52462	3.63915	4.89017	5.16328
	LN(shear stress)	0.8593817	1.085453	1.2597726	1.29175	1.5872271	1.641572
	shear rate	55.197124	110.3942	165.59137	183.9904	331.18275	367.98083
	Vicosity	0.0427866	0.02682	0.021285	0.019779	0.0147658	0.0140314
1000B	Dail Reading	33	40.5	46.1	48	62.8	66.3
	Shear stress	2.5379	3.19865	3.69201	3.8594	5.16328	5.47163
	LN(shear stress)	0.931337	1.162729	1.306171	1.350512	1.641572	1.6995766
	shear rate	55.114796	110.2296	165.34439	183.716	330.68878	367.43198
	Vicosity	0.0460475	0.029018	0.0223292	0.021007	0.0156137	0.0148915

n&k values					
Total 500ppm					
PEO fraction	100%	90%	80%	60%	50%
n	0.6922	0.6478	0.5507	0.468	0.4864
k	0.0157	0.0295	0.0593	0.1214	0.1266
PEO fraction	40%	20%	10%	0%	
n	0.4671	0.4374	0.4478	0.4686	
k	0.1602	0.2014	0.2111	0.2052	
Total 1000ppm					
PEO fraction	100%	90%	80%	60%	50%
n	0.7102	0.5923	0.5385	0.4436	0.4211
k	0.02335	0.0646	0.1123	0.2535	0.3079
PEO fraction	40%	20%	10%	0%	
n	0.4629	0.4164	0.4417	0.4478	
k	0.2865	0.4105	0.3799	0.3925	

Flow Data

Total 500ppm

500ppm PAM in 1inch pipe											
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Virk's	FR in vol
1.066	2	2	1.018	0.108044	0.113981	148.8599	0.022298	0.438819	0.06775	0.031858	0.000108
1.168	2	2	1.112	0.264512	0.279048	577.209	0.033775	0.664693	0.017122	0.014516	0.000265
1.257	2	2	1.254	0.401038	0.423076	1083.681	0.051113	1.005908	0.011272	0.010074	0.000402
1.353	2	2	1.45	0.548302	0.578433	1739.803	0.075045	1.47688	0.008854	0.007655	0.00055
1.537	2	2	1.934	0.830558	0.8762	3261.956	0.134141	2.639893	0.006897	0.005316	0.000833
1.645	2	2	2.289	0.99623	1.050976	4295.729	0.177487	3.492929	0.006343	0.004532	0.000999
1.838	2	2	2.993	1.292292	1.363307	6369.058	0.263445	5.184584	0.005595	0.003606	0.001296
2.052	2	2	3.868	1.620568	1.709623	8971.645	0.370283	7.287138	0.005001	0.002956	0.001625
2.113	2	2	4.13	1.714142	1.808339	9767.265	0.402273	7.916703	0.004856	0.002814	0.001719
2.26	2	2	4.786	1.93964	2.046229	11776.45	0.482371	9.493017	0.004548	0.002525	0.001945
2.376	2	3	1.437	2.117584	2.233952	13449.69	0.52559	10.34357	0.004157	0.002338	0.002124
2.501	2	3	1.498	2.309334	2.436239	15335.34	0.602334	11.85388	0.004006	0.002166	0.002316
2.751	2	3	1.622	2.692834	2.840813	19350.18	0.758338	14.92404	0.003709	0.001893	0.002701
3.013	2	3	1.77	3.094742	3.264808	23885.2	0.944537	18.58842	0.003498	0.001675	0.003104
3.191	2	3	1.869	3.367794	3.552865	27146.25	1.069089	21.03959	0.003343	0.001556	0.003378
3.375	2	3	1.987	3.65005	3.850631	30663.04	1.217545	23.96119	0.003241	0.001449	0.003661
3.565	2	3	2.101	3.94151	4.158108	34444.09	1.360968	26.78375	0.003107	0.001355	0.003953
3.764	2	3	2.242	4.246776	4.480149	38561.19	1.53836	30.27481	0.003025	0.001269	0.00426
4.021	2	3	2.413	4.641014	4.896052	44106.74	1.753495	34.50866	0.002888	0.001174	0.004655
4.261	2	3	2.588	5.009174	5.284443	49509.18	1.973663	38.84154	0.00279	0.001098	0.005024
4.411	2	3	2.692	5.239274	5.527188	52991.78	2.104505	41.4165	0.002719	0.001055	0.005255
4.717	2	3	2.929	5.708678	6.022387	60340.92	2.402675	47.28446	0.002615	0.000979	0.005726
5.089	2	3	3.219	6.279326	6.624394	69701.3	2.767524	54.46466	0.00249	0.0009	0.006298

500ppm PAM in 1.5inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.085	2	2	1.043	0.13719	0.144729	423.7479	0.02535	0.498892	0.047773	0.000138
1.222	2	2	1.19	0.347348	0.366436	1358.516	0.043299	0.852121	0.012729	0.000348
1.327	2	2	1.39	0.508418	0.536357	2190.6	0.067719	1.332705	0.009292	0.00051
1.406	2	2	1.587	0.629604	0.664203	2864.191	0.091773	1.80608	0.008212	0.000631
1.522	2	2	1.856	0.807548	0.851925	3913.554	0.124618	2.452465	0.006778	0.00081
1.622	2	2	2.089	0.960948	1.013755	4867.382	0.153067	3.012345	0.005879	0.000964
1.758	2	2	2.474	1.169572	1.233844	6227.362	0.200075	3.937469	0.005188	0.001173
1.971	2	2	3.062	1.496314	1.578541	8481.79	0.27187	5.350385	0.004307	0.001501
2.164	2	2	3.705	1.792376	1.890873	10636.95	0.350381	6.895462	0.003868	0.001798
2.317	2	2	4.199	2.027078	2.138472	12411.89	0.410698	8.082504	0.003545	0.002033
2.465	2	2	4.686	2.25411	2.37798	14179.39	0.470161	9.252725	0.003282	0.002261
2.627	2	3	1.428	2.502618	2.640145	16166.58	0.514267	10.12073	0.002912	0.00251
2.76	2	3	1.48	2.70664	2.855378	17836.21	0.579688	11.40822	0.002807	0.002715
3.082	2	3	1.612	3.200588	3.37647	22008.99	0.745757	14.67645	0.002582	0.00321
3.312	2	3	1.709	3.553408	3.748679	25093.17	0.867793	17.0781	0.002438	0.003564
3.574	2	3	1.829	3.955316	4.172673	28702.28	1.018765	20.04922	0.00231	0.003967
3.859	2	3	1.964	4.392506	4.633888	32735.36	1.188608	23.39172	0.002185	0.004406
4.289	2	3	2.187	5.052126	5.329756	39013.82	1.469165	28.91305	0.002042	0.005067
4.572	2	3	2.339	5.486248	5.787734	43263.02	1.660396	32.67647	0.001957	0.005503
4.887	2	3	2.53	5.969458	6.297498	48094.06	1.900693	37.4055	0.001892	0.005987
5.121	2	3	2.668	6.328414	6.67618	51748.22	2.074311	40.82228	0.001837	0.006347

500ppm PEO in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.144	1	2	1.235	0.227696	0.599946	4090.643	0.048794	2.034259	0.011336	0.000228
1.271	1	2	1.694	0.422514	1.113264	9181.576	0.104837	4.370795	0.007074	0.000424
1.36	1	2	2.043	0.55904	1.47299	13241.83	0.14745	6.147378	0.005683	0.000561
1.463	1	2	2.635	0.717042	1.889303	18336.8	0.219734	9.16095	0.005148	0.000719
1.546	1	2	3.179	0.844364	2.224778	22706.9	0.286156	11.93018	0.004835	0.000847
1.659	1	2	3.954	1.017706	2.681509	28987.5	0.380783	15.87531	0.004428	0.001021
1.707	1	2	4.332	1.091338	2.875519	31760.36	0.426937	17.79952	0.004318	0.001095
1.727	1	2	4.492	1.122018	2.956357	32933.05	0.446473	18.614	0.004272	0.001125
1.751	1	2	4.714	1.158834	3.053362	34353.36	0.473579	19.74409	0.004248	0.001162
1.853	1	3	1.456	1.315302	3.465632	40541.87	0.549494	22.90904	0.003826	0.001319
1.968	1	3	1.551	1.491712	3.930447	47795.55	0.669013	27.89195	0.003621	0.001496
2.099	1	3	1.605	1.692666	4.459932	56385.54	0.736951	30.72434	0.003098	0.001698
2.337	1	3	1.879	2.057758	5.421897	72794.62	1.08167	45.0961	0.003077	0.002064
2.594	1	3	2.127	2.451996	6.460658	91549.54	1.393679	58.10411	0.002792	0.002459
2.89	1	3	2.422	2.90606	7.657052	114327.8	1.764818	73.57736	0.002517	0.002915
3.282	1	3	2.851	3.507388	9.241465	146208.3	2.304543	96.07913	0.002257	0.003518
3.644	1	3	3.232	4.062696	10.70462	177194.2	2.783879	116.0632	0.002032	0.004075
3.757	1	3	3.367	4.236038	11.16135	187145.9	2.953723	123.1442	0.001983	0.004249
3.89	1	3	3.549	4.44006	11.69892	199020.3	3.182697	132.6904	0.001945	0.004453

500ppm PEO in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.121	2	2	1.081	0.192414	0.202988	1361.032	0.02999	0.590203	0.028731	0.000193
1.191	2	2	1.156	0.299794	0.316269	2430.707	0.039148	0.770422	0.015449	0.000301
1.288	2	2	1.264	0.448592	0.473244	4117.513	0.052334	1.029937	0.009224	0.00045
1.408	2	2	1.585	0.632672	0.667439	6455.426	0.091529	1.801274	0.00811	0.000635
1.586	2	2	2.087	0.905724	0.955496	10320.55	0.152823	3.007539	0.006608	0.000908
1.723	2	2	2.604	1.115882	1.177203	13558.72	0.215948	4.249848	0.006151	0.001119
1.898	2	2	3.37	1.384332	1.460405	17974.53	0.309477	6.090484	0.005728	0.001388
2.099	2	2	4.37	1.692666	1.785683	23381.32	0.431577	8.493403	0.005343	0.001698
2.26	2	3	1.433	1.93964	2.046229	27939.92	0.520557	10.24453	0.004908	0.001945
2.389	2	3	1.509	2.137526	2.25499	31725	0.616173	12.12624	0.004783	0.002144
2.556	2	3	1.62	2.393704	2.525245	36786.79	0.755822	14.87452	0.004679	0.002401
2.771	2	3	1.778	2.723514	2.873179	43551.79	0.954602	18.78649	0.004565	0.002732
3.039	2	3	1.994	3.134626	3.306883	52342.59	1.226351	24.1345	0.004427	0.003144
3.313	2	3	2.23	3.554942	3.750297	61705.27	1.523263	29.9777	0.004275	0.003566
3.539	2	3	2.44	3.901626	4.116032	69690.66	1.787464	35.17716	0.004165	0.003913
3.758	2	3	2.642	4.237572	4.47044	77640.31	2.0416	40.17854	0.004033	0.00425
3.979	2	3	2.86	4.576586	4.828083	85861.77	2.315866	45.57607	0.003922	0.00459
4.259	2	3	3.152	5.006106	5.281207	96549.42	2.683231	52.80579	0.003798	0.005021
4.455	2	3	3.361	5.30677	5.598393	104202.1	2.946174	57.98049	0.003711	0.005323
4.712	2	3	3.627	5.701008	6.014296	114439.8	3.280829	64.56646	0.00358	0.005718
4.938	2	3	3.865	6.047692	6.380031	123625.1	3.580257	70.45918	0.003472	0.006066

400ppm PAM with 100ppm PEO in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.173	1	2	1.192	0.272182	0.717161	1582.287	0.043543	1.815368	0.00708	0.000273
1.251	1	2	1.362	0.391834	1.032426	2796.117	0.0643	2.680751	0.005045	0.000393
1.364	1	2	1.543	0.565176	1.489158	4956.057	0.0864	3.602131	0.003258	0.000567
1.477	1	2	1.835	0.738518	1.945889	7527.921	0.122054	5.088555	0.002696	0.000741
1.576	1	2	2.021	0.890384	2.346034	10082.86	0.144764	6.035387	0.0022	0.000893
1.647	1	2	2.267	0.999298	2.633007	12075.29	0.174801	7.287648	0.002109	0.001002
1.732	1	2	2.496	1.129688	2.976566	14626.05	0.202762	8.453371	0.001914	0.001133
1.849	1	2	2.844	1.309166	3.449465	18415.77	0.245252	10.22486	0.001724	0.001313
2.027	1	2	3.447	1.582218	4.168918	24759.82	0.318879	13.29443	0.001534	0.001587
2.231	1	2	4.062	1.895154	4.993459	32826.25	0.39397	16.42508	0.001321	0.001901
2.472	1	2	4.944	2.264848	5.96755	43366.87	0.501662	20.9149	0.001178	0.002272
2.732	1	3	1.493	2.663688	7.018436	55877.16	0.596043	24.84975	0.001012	0.002672
3.114	1	3	1.653	3.249676	8.562431	76238.67	0.797339	33.24202	0.000909	0.003259
3.309	1	3	1.771	3.548806	9.350595	87484.79	0.945795	39.43132	0.000905	0.003559
3.552	1	3	1.885	3.921568	10.33277	102262	1.089219	45.41081	0.000853	0.003933
3.792	1	3	2.027	4.289728	11.30282	117654.6	1.267869	52.85895	0.00083	0.004303
4.032	1	3	2.121	4.657888	12.27287	133809.3	1.38613	57.7894	0.00077	0.004672
4.184	1	3	2.25	4.891056	12.88723	144422.4	1.548425	64.55567	0.00078	0.004906

400ppm PEO with 100ppm PAM in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.116	2	2	1.036	0.184744	0.194896	252.3972	0.024496	0.482072	0.025456	0.000185
1.171	2	2	1.121	0.269114	0.283903	454.3182	0.034874	0.68632	0.01708	0.00027
1.221	2	2	1.192	0.345814	0.364818	672.2597	0.043543	0.856927	0.012915	0.000347
1.31	2	2	1.368	0.48234	0.508846	1130.706	0.065033	1.279841	0.009915	0.000484
1.401	2	2	1.58	0.621934	0.656111	1682.08	0.090918	1.789259	0.008337	0.000624
1.528	2	2	1.914	0.816752	0.861635	2574.98	0.131699	2.591834	0.007002	0.000819
1.63	2	2	2.205	0.97322	1.026701	3386.26	0.167231	3.291084	0.006262	0.000976
1.794	2	2	2.751	1.224796	1.292102	4850.094	0.233897	4.603077	0.00553	0.001228
1.931	2	2	3.241	1.434954	1.513809	6211.789	0.293726	5.780508	0.00506	0.001439
2.116	2	2	3.931	1.718744	1.813194	8235.362	0.377975	7.438522	0.004538	0.001724
2.269	2	2	4.558	1.953446	2.060794	10058.84	0.454532	8.945152	0.004225	0.001959
2.363	2	2	4.923	2.097642	2.212914	11242.92	0.499098	9.822217	0.004023	0.002104
2.599	2	3	1.493	2.459666	2.594832	14418.65	0.596043	11.73009	0.003494	0.002467
2.768	2	3	1.572	2.718912	2.868325	16862.72	0.695433	13.68607	0.003337	0.002727
2.955	2	3	1.65	3.00577	3.170946	19724.02	0.793565	15.6173	0.003115	0.003015
3.033	2	3	1.697	3.125422	3.297174	20964.57	0.852696	16.78099	0.003096	0.003135
3.196	2	3	1.781	3.375464	3.560956	23643.71	0.958376	18.86077	0.002983	0.003386
3.41	2	3	1.894	3.70374	3.907272	27333.76	1.100541	21.65857	0.002846	0.003715
3.62	2	3	2.009	4.02588	4.247114	31138.47	1.245223	24.50589	0.002725	0.004038
3.868	2	3	2.149	4.406312	4.648452	35856.98	1.421357	27.9722	0.002597	0.00442
4.113	2	3	2.295	4.782142	5.044935	40749.26	1.60504	31.58706	0.002489	0.004797
4.377	2	3	2.458	5.187118	5.472166	46268.48	1.81011	35.62283	0.002386	0.005203
4.685	2	3	2.656	5.65959	5.970602	53020.46	2.059214	40.52517	0.00228	0.005677
5.121	2	3	2.962	6.328414	6.67618	63131.35	2.444192	48.10152	0.002165	0.006347

400ppm PEO +100ppm PAM in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.146	1	2	1.22	0.230764	0.60803	2299.703	0.046962	1.957901	0.010623	0.000231
1.205	1	2	1.385	0.32127	0.8465	3714.832	0.067109	2.797833	0.007832	0.000322
1.29	1	2	1.711	0.45166	1.190059	6086.263	0.106913	4.457334	0.006313	0.000453
1.402	1	2	2.227	0.623468	1.642749	9710.831	0.169917	7.084028	0.005265	0.000625
1.491	1	2	2.644	0.759994	2.002475	12938.69	0.220832	9.206764	0.004605	0.000762
1.561	1	2	3.033	0.867374	2.285406	15670.21	0.268329	11.18697	0.004296	0.00087
1.716	1	2	3.906	1.105144	2.911896	22261.74	0.374923	15.63097	0.003698	0.001108
1.762	1	2	4.207	1.175708	3.097822	24351.02	0.411675	17.16321	0.003587	0.001179
1.971	1	3	1.456	1.496314	3.942573	34537.64	0.549494	22.90904	0.002956	0.001501
2.164	1	3	1.585	1.792376	4.722654	44867	0.711789	29.67531	0.002669	0.001798
2.368	1	3	1.743	2.105312	5.547195	56651.94	0.910568	37.96267	0.002475	0.002112
2.518	1	3	1.867	2.335412	6.153476	65841.76	1.066573	44.46668	0.002356	0.002342
2.619	1	3	1.948	2.490346	6.561705	72265.56	1.168479	48.71526	0.002269	0.002498
2.787	1	3	2.094	2.748058	7.240739	83351.31	1.352161	56.37321	0.002157	0.002756
3.056	1	3	2.352	3.160704	8.328002	102086.6	1.676751	69.90574	0.002022	0.00317
3.163	1	3	2.459	3.324842	8.760482	109858.8	1.811368	75.51807	0.001974	0.003335
3.471	1	3	2.761	3.797314	10.00538	133188.7	2.191314	91.35848	0.001831	0.003809
3.712	1	3	3.021	4.167008	10.97947	152385.5	2.51842	104.9959	0.001747	0.00418
3.789	1	3	3.107	4.285126	11.29069	158685.4	2.626617	109.5068	0.001723	0.004298
3.979	1	3	3.311	4.576586	12.05865	174564.2	2.883269	120.2069	0.001658	0.00459

400ppm PEO+100ppm PAM in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.146	2	2	1.085	0.230764	0.243445	785.233	0.030479	0.599815	0.0203	0.000231
1.203	2	2	1.152	0.318202	0.335688	1250.911	0.038659	0.76081	0.013542	0.000319
1.309	2	2	1.346	0.480806	0.507228	2275.297	0.062347	1.226976	0.009566	0.000482
1.405	2	2	1.563	0.62807	0.662584	3351.291	0.088842	1.74841	0.007988	0.00063
1.534	2	2	1.937	0.825956	0.871345	4984.306	0.134508	2.647101	0.006993	0.000828
1.695	2	2	2.486	1.07293	1.131891	7282.26	0.201541	3.966304	0.00621	0.001076
1.813	2	2	2.947	1.253942	1.32285	9128.356	0.257829	5.07405	0.005816	0.001258
1.975	2	2	3.679	1.50245	1.585014	11863.02	0.347206	6.832986	0.005456	0.001507
2.088	2	2	4.213	1.675792	1.767882	13897.01	0.412407	8.116145	0.005209	0.001681
2.212	2	2	4.836	1.866008	1.968551	16240.3	0.488476	9.613163	0.004976	0.001872
2.314	2	3	1.444	2.022476	2.133617	18250.55	0.534396	10.51688	0.004634	0.002029
2.486	2	3	1.541	2.286324	2.411965	21800.05	0.656432	12.91853	0.004454	0.002293
2.574	2	3	1.59	2.421316	2.554375	23689.99	0.718079	14.13174	0.004344	0.002429
2.767	2	3	1.717	2.717378	2.866706	28000.95	0.877858	17.27617	0.004217	0.002726
2.976	2	3	1.851	3.037984	3.204931	32913.21	1.046443	20.59392	0.004022	0.003047
3.189	2	3	2.001	3.364726	3.549628	38165.18	1.235158	24.30782	0.00387	0.003375
3.374	2	3	2.142	3.648516	3.849013	42917.47	1.41255	27.79888	0.003764	0.003659
3.675	2	3	2.373	4.11025	4.336121	51008	1.703171	33.51828	0.003576	0.004123
3.899	2	3	2.544	4.453866	4.69862	57302.53	1.918306	37.75213	0.00343	0.004467
4.173	2	3	2.794	4.874182	5.142033	65303.29	2.232831	43.94195	0.003334	0.004889
4.346	2	3	2.948	5.139564	5.421999	70518.74	2.426579	47.75489	0.003258	0.005155
4.539	2	3	3.127	5.435626	5.73433	76481.48	2.651779	52.18681	0.003183	0.005452
5	2	3	3.315	5.754698	6.070936	83072.97	2.888302	56.84156	0.003093	0.005772
5.004	2	3	3.578	6.148936	6.486839	91446.45	3.219182	63.35326	0.00302	0.006167

450ppm PAM +50ppm PEO in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.168	1	2	1.312	0.264512	0.696951	1366.475	0.058195	2.426227	0.010019	0.000265
1.27	1	2	1.555	0.42098	1.109222	2810.998	0.087866	3.663217	0.005972	0.000422
1.324	1	2	1.679	0.503816	1.327483	3714.911	0.103006	4.294438	0.004888	0.000505
1.388	1	2	1.844	0.601992	1.586163	4897.367	0.123152	5.134369	0.004093	0.000604
1.458	1	2	2.038	0.709372	1.869094	6318.421	0.14684	6.121925	0.003515	0.000712
1.517	1	2	2.2	0.799878	2.107564	7612.992	0.16662	6.946585	0.003137	0.000802
1.58	1	2	2.371	0.89652	2.362202	9087.522	0.187499	7.817059	0.00281	0.000899
1.633	1	2	2.545	0.977822	2.576421	10398.32	0.208745	8.702805	0.00263	0.000981
1.702	1	2	2.748	1.083668	2.85531	12196.85	0.233531	9.736176	0.002395	0.001087
1.766	1	2	2.963	1.181844	3.11399	13954.35	0.259782	10.83063	0.00224	0.001185
1.853	1	2	3.222	1.315302	3.465632	16475.3	0.291406	12.14907	0.002029	0.001319
1.926	1	2	3.535	1.427284	3.760689	18703.07	0.329624	13.74239	0.001949	0.001432
2.036	1	2	3.869	1.596024	4.205295	22245.37	0.370405	15.44262	0.001752	0.001601
2.111	1	2	4.13	1.711074	4.508435	24783.45	0.402273	16.77124	0.001655	0.001716
2.208	1	2	4.495	1.859872	4.900496	28208.08	0.44684	18.62927	0.001556	0.001865
2.393	1	3	1.431	2.143662	5.648242	35164.36	0.518041	21.59775	0.001358	0.00215
2.613	1	3	1.505	2.481142	6.537454	44122.5	0.611141	25.47917	0.001196	0.002489
2.797	1	3	1.605	2.763398	7.281158	52154.33	0.736951	30.72434	0.001162	0.002772
3.041	1	3	1.704	3.137694	8.267374	63521.52	0.861502	35.91705	0.001054	0.003147
3.236	1	3	1.818	3.436824	9.055539	73165.31	1.004926	41.89655	0.001025	0.003447
2.437	1	3	1.924	2.211158	5.826084	36897.82	1.138284	47.45642	0.002804	0.002218
3.646	1	3	2.044	4.065764	10.71271	94971.3	1.289256	53.75063	0.000939	0.004078
3.898	1	3	2.187	4.452332	11.73126	109350.2	1.469165	61.25122	0.000893	0.004466
4.026	1	3	2.248	4.648684	12.24862	116926.1	1.545909	64.45077	0.000862	0.004663
4.183	1	3	2.383	4.889522	12.88319	126462.3	1.715752	71.53174	0.000864	0.004904

450ppm PAM +50ppm PEO in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.148	2	2	1.103	0.233832	0.246682	334.552	0.032676	0.643067	0.021197	0.000235
1.193	2	2	1.164	0.302862	0.319505	499.8493	0.040124	0.789645	0.015516	0.000304
1.308	2	2	1.378	0.479272	0.505609	1019.179	0.066254	1.30387	0.01023	0.000481
1.384	2	2	1.542	0.595856	0.6286	1428.977	0.086278	1.697949	0.008619	0.000598
1.46	2	2	1.723	0.71244	0.751591	1885.762	0.108378	2.132877	0.007573	0.000715
1.565	2	2	2.012	0.87351	0.921512	2587.539	0.143665	2.82732	0.006678	0.000876
1.683	2	2	2.373	1.054522	1.112471	3466.075	0.187743	3.694774	0.005988	0.001058
1.796	2	2	2.704	1.227864	1.295339	4389.651	0.228158	4.49014	0.005368	0.001232
1.956	2	2	3.246	1.473304	1.554267	5824.711	0.294337	5.792522	0.00481	0.001478
2.024	2	2	3.486	1.577616	1.664311	6477.219	0.323641	6.369223	0.004612	0.001582
2.129	2	2	3.83	1.738686	1.834232	7532.207	0.365643	7.195827	0.00429	0.001744
2.273	2	2	4.371	1.959582	2.067267	9068.742	0.431699	8.495806	0.003988	0.001965
2.334	2	2	4.594	2.053156	2.165983	9749.724	0.458927	9.031657	0.003861	0.002059
2.434	2	3	1.401	2.206556	2.327813	10903.48	0.480298	9.452231	0.003499	0.002213
2.619	2	3	1.478	2.490346	2.627198	13156.04	0.577172	11.3587	0.003301	0.002498
2.824	2	3	1.559	2.804816	2.958949	15822.97	0.679078	13.3642	0.003062	0.002813
3.055	2	3	1.662	3.15917	3.332776	19032.16	0.808662	15.91441	0.002874	0.003169
3.284	2	3	1.771	3.510456	3.703366	22416.32	0.945795	18.61318	0.002722	0.003521
3.483	2	3	1.875	3.815722	4.025408	25513.75	1.076638	21.18815	0.002623	0.003827
3.638	2	3	1.962	4.053492	4.276244	28023.58	1.186092	23.34221	0.00256	0.004066
3.829	2	3	2.061	4.346486	4.585339	31229.8	1.310644	25.79338	0.002461	0.00436
4.071	2	3	2.193	4.717714	4.976967	35466.4	1.476713	29.06161	0.002353	0.004732
4.276	2	3	2.312	5.032184	5.308718	39202.83	1.626427	32.00797	0.002278	0.005047
4.451	2	3	2.421	5.300634	5.59192	42496.44	1.76356	34.70673	0.002226	0.005317
4.593	2	3	2.513	5.518462	5.821718	45237.74	1.879305	36.98459	0.002189	0.005535
4.781	2	3	2.637	5.806854	6.125958	48959.84	2.03531	40.05474	0.002141	0.005824

450ppm PEO+50ppm PAM in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.146	1	2	1.253	0.230764	0.60803	2794.201	0.050991	2.125888	0.011534	0.000231
1.232	1	2	1.481	0.362688	0.955631	5149.707	0.07883	3.28652	0.007219	0.000364
1.32	1	2	1.825	0.49768	1.311315	7899.468	0.120833	5.03765	0.005876	0.000499
1.386	1	2	2.101	0.598924	1.578079	10147.14	0.154532	6.442626	0.005189	0.000601
1.474	1	2	2.562	0.733916	1.933763	13357	0.21082	8.789344	0.004715	0.000736
1.572	1	2	3.096	0.884248	2.329867	17184.59	0.276022	11.50767	0.004252	0.000887
1.618	1	2	3.637	0.954812	2.515793	19064.56	0.342078	14.26162	0.00452	0.000958
1.762	1	2	4.224	1.175708	3.097822	25260.43	0.41375	17.24974	0.003605	0.001179
1.924	1	3	1.432	1.424216	3.752605	32737.62	0.519299	21.6502	0.003084	0.001429
2.063	1	3	1.547	1.637442	4.314425	39534.56	0.663981	27.68214	0.002983	0.001642
2.254	1	3	1.688	1.930436	5.086422	49390.68	0.841373	35.07783	0.00272	0.001936
2.482	1	3	1.883	2.280188	6.007969	61862.82	1.086702	45.30591	0.002518	0.002287
2.737	1	3	2.122	2.671358	7.038645	76631.78	1.387388	57.84186	0.002342	0.002679
2.94	1	3	2.315	2.98276	7.859145	88953.01	1.630202	67.96503	0.002207	0.002992
3.177	1	3	2.558	3.346318	8.817068	103920.6	1.93592	80.71079	0.002082	0.003356
3.453	1	3	2.858	3.769702	9.932625	122085.5	2.31335	96.44629	0.001961	0.003781
3.642	1	3	3.086	4.059628	10.69654	134951.2	2.600197	108.4053	0.0019	0.004072
3.941	1	3	3.404	4.518294	11.90506	155969	3.000272	125.0849	0.00177	0.004532

450ppm PEO+50ppm PAM in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.139	2	2	1.079	0.220026	0.232117	1022.119	0.029746	0.585397	0.021794	0.000221
1.231	2	2	1.215	0.361154	0.381001	1997.651	0.046352	0.912194	0.012605	0.000362
1.318	2	2	1.366	0.494612	0.521792	3056.277	0.064789	1.275035	0.009393	0.000496
1.399	2	2	1.557	0.618866	0.652875	4138.138	0.08811	1.733992	0.00816	0.000621
1.518	2	2	1.886	0.801412	0.845452	5869.51	0.128281	2.524553	0.007084	0.000804
1.652	2	2	2.319	1.006968	1.062304	7992.558	0.18115	3.565016	0.006337	0.00101
1.782	2	2	2.811	1.206388	1.272683	10204.57	0.241223	4.747253	0.005879	0.00121
1.895	2	2	3.315	1.37973	1.45555	12235.95	0.302762	5.958324	0.005641	0.001384
2.089	2	2	4.235	1.677326	1.7695	15934.4	0.415094	8.169009	0.005233	0.001682
2.287	2	3	1.436	1.981058	2.089923	19955.95	0.524332	10.31881	0.004739	0.001987
2.423	2	3	1.509	2.189682	2.310012	22849.21	0.616173	12.12624	0.004558	0.002196
2.595	2	3	1.62	2.45353	2.588359	26649.18	0.755822	14.87452	0.004453	0.002461
2.809	2	3	1.766	2.781806	2.934675	31581.06	0.939505	18.48938	0.004306	0.00279
3.096	2	3	1.974	3.222064	3.399126	38521.84	1.201189	23.63932	0.004104	0.003232
3.285	2	3	2.119	3.51199	3.704985	43281.78	1.383614	27.22942	0.003979	0.003523
3.523	2	3	3.214	3.877082	4.09014	49474.84	2.761233	54.34087	0.006515	0.003889
3.778	2	3	2.53	4.268252	4.502806	56341.98	1.900693	37.4055	0.0037	0.004281
4.009	2	3	2.726	4.622606	4.876632	62757.85	2.147281	42.25832	0.003564	0.004637
4.329	2	3	3.024	5.113486	5.394488	71934.17	2.522194	49.6366	0.003421	0.005129
4.567	2	3	3.262	5.478578	5.779643	78965	2.821622	55.52931	0.003334	0.005495
4.731	2	3	3.436	5.730154	6.045044	83907.44	3.040532	59.83743	0.003284	0.005747
4.974	2	3	3.682	6.102916	6.43829	91371.69	3.350024	65.92823	0.00319	0.006121

300ppm PAM +200ppm PEO in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.102	1	2	1.102	0.163268	0.430188	773.2411	0.032554	1.357223	0.01471	0.000164
1.183	1	2	1.383	0.287522	0.757579	1841.009	0.066864	2.787652	0.009743	0.000288
1.284	1	2	1.768	0.442456	1.165808	3564.619	0.113873	4.747492	0.007007	0.000444
1.412	1	2	2.031	0.638808	1.683168	6259.089	0.145985	6.086292	0.004309	0.000641
1.524	1	2	2.382	0.810616	2.135857	9017.407	0.188842	7.873055	0.003462	0.000813
1.608	1	2	2.699	0.939472	2.475374	11305.57	0.227548	9.486741	0.003105	0.000942
1.667	1	2	2.888	1.029978	2.713844	13017.36	0.250625	10.44884	0.002846	0.001033
1.729	1	2	3.145	1.125086	2.96444	14904.64	0.282005	11.7571	0.002684	0.001128
1.909	1	2	3.876	1.401206	3.691977	20865.64	0.37126	15.47825	0.002278	0.001405
2.011	1	2	4.313	1.557674	4.104248	24541.79	0.424617	17.7028	0.002108	0.001562
2.08	1	2	4.613	1.66352	4.383137	27143.93	0.461247	19.22995	0.002008	0.001669
2.187	1	3	1.414	1.827658	4.815617	31355.78	0.496653	20.70607	0.001791	0.001833
2.342	1	3	1.448	2.065428	5.442107	37821.42	0.539429	22.48943	0.001523	0.002072
2.511	1	3	1.571	2.324674	6.125183	45337.26	0.694175	28.94098	0.001547	0.002332
2.811	1	3	1.731	2.784874	7.337744	59800.02	0.895471	37.33325	0.001391	0.002793
2.996	1	3	1.843	3.068664	8.08549	69391.06	1.036378	43.20784	0.001326	0.003078
3.183	1	3	1.952	3.355522	8.84132	79578.65	1.173511	48.92507	0.001255	0.003366
3.382	1	3	2.085	3.660788	9.645652	90941.55	1.340839	55.90114	0.001205	0.003672
3.587	1	3	2.209	3.975258	10.47424	103187.2	1.496843	62.40515	0.001141	0.003987
3.677	1	3	2.286	4.113318	10.838	108731.2	1.593717	66.44393	0.001135	0.004126
3.901	1	3	2.419	4.456934	11.74338	122960.7	1.761044	73.42001	0.001068	0.00447

300ppm PAM +200ppm PEO in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.143	2	2	1.164	0.226162	0.23859	387.9057	0.040124	0.789645	0.027824	0.000227
1.262	2	2	1.369	0.408708	0.431168	960.8851	0.065155	1.282244	0.013835	0.00041
1.421	2	2	1.648	0.652614	0.688477	1968.897	0.099221	1.952658	0.008263	0.000655
1.502	2	2	1.748	0.776868	0.819559	2571.873	0.111431	2.19295	0.006549	0.000779
1.624	2	2	2.036	0.964016	1.016992	3580.461	0.146596	2.88499	0.005595	0.000967
1.865	2	2	2.712	1.33371	1.407001	5889.018	0.229135	4.509364	0.004569	0.001338
1.956	2	2	3.032	1.473304	1.554267	6859.803	0.268207	5.278298	0.004383	0.001478
2.04	2	2	3.324	1.60216	1.690204	7800.634	0.30386	5.97995	0.004199	0.001607
2.189	2	2	3.829	1.830726	1.93133	9569.993	0.365521	7.193424	0.003868	0.001836
2.372	2	2	4.581	2.111448	2.227479	11909.28	0.45734	9.000419	0.003639	0.002118
2.499	2	3	1.413	2.306266	2.433002	13634.53	0.495395	9.749342	0.003304	0.002313
2.689	2	3	1.491	2.597726	2.740479	16363.13	0.593527	11.68057	0.00312	0.002606
2.951	2	3	1.618	2.999634	3.164473	20400.19	0.753306	14.825	0.002969	0.003009
3.172	2	3	1.723	3.338648	3.522117	24039.07	0.885406	17.42473	0.002817	0.003349
3.388	2	3	1.84	3.669992	3.871669	27791.46	1.032604	20.32157	0.002719	0.003681
3.663	2	3	1.994	4.091842	4.316701	32835.73	1.226351	24.1345	0.002598	0.004104
3.906	2	3	2.13	4.464604	4.709948	37530.86	1.397453	27.50177	0.002487	0.004478
4.191	2	3	2.309	4.901794	5.171163	43309.34	1.622653	31.93369	0.002395	0.004917
4.366	2	3	3.419	5.170244	5.454365	46997.78	3.019144	59.41653	0.004006	0.005186
4.522	2	3	2.524	5.409548	5.706819	50373.11	1.893144	37.25694	0.002295	0.005426
4.673	2	3	2.629	5.641182	5.951182	53716.97	2.025245	39.85667	0.002257	0.005658

300ppm PEO +200ppm PAM in 1inch pipe										
FR signa	Measure	Channel	PD signa	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.121	1	2	1.192	0.192414	0.506983	1306.577	0.043543	1.815368	0.014167	0.000193
1.269	1	2	1.574	0.419446	1.10518	4311.459	0.090185	3.759936	0.006175	0.000421
1.367	1	2	1.862	0.569778	1.501283	6893.276	0.12535	5.225998	0.004651	0.000571
1.455	1	2	2.194	0.70477	1.856968	9547.577	0.165887	6.916042	0.004023	0.000707
1.565	1	2	2.564	0.87351	2.301574	13264.99	0.211064	8.799525	0.003332	0.000876
1.644	1	2	2.883	0.994696	2.620881	16186.25	0.250014	10.42339	0.003044	0.000998
1.71	1	2	3.164	1.09594	2.887645	18777.51	0.284324	11.85382	0.002851	0.001099
1.776	1	2	3.423	1.197184	3.154408	21499.44	0.315948	13.17226	0.002655	0.001201
1.819	1	2	3.647	1.263146	3.328209	23340.57	0.343299	14.31253	0.002592	0.001267
1.946	1	2	4.192	1.457964	3.841526	29076.67	0.409843	17.08685	0.002322	0.001462
2.09	1	2	4.906	1.67886	4.423555	36091.65	0.497023	20.72146	0.002124	0.001684
2.213	1	3	1.457	1.867542	4.920706	42488.44	0.550752	22.96149	0.001902	0.001873
2.737	1	3	1.541	2.671358	7.038645	73525.52	0.656432	27.36743	0.001108	0.002679
2.518	1	3	1.622	2.335412	6.153476	59843.56	0.758338	31.61602	0.001675	0.002342
2.758	1	3	1.771	2.703572	7.123525	74888.21	0.945795	39.43132	0.001559	0.002712
3.031	1	3	1.941	3.122354	8.226955	93375.12	1.159672	48.3481	0.001433	0.003132
3.273	1	3	2.119	3.493582	9.205088	110911.3	1.383614	57.6845	0.001366	0.003504
3.558	1	3	2.324	3.930772	10.35702	132869.3	1.641524	68.4371	0.00128	0.003943
3.793	1	3	2.495	4.291262	11.30686	151986.4	1.85666	77.40633	0.001214	0.004304
4.115	1	3	2.752	4.78521	12.60834	179594.4	2.179991	90.88641	0.001147	0.0048

300ppm PEO+200ppm PAM in 1.5inch pipe										
FR signa	Measure	Channel	PD signa	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.15	2	2	1.105	0.2369	0.249918	547.6868	0.032921	0.647873	0.020806	0.000238
1.227	2	2	1.23	0.355018	0.374527	1017.846	0.048183	0.948238	0.013559	0.000356
1.318	2	2	1.415	0.494612	0.521792	1691.656	0.070772	1.392778	0.010261	0.000496
1.462	2	2	1.738	0.715508	0.754827	2978.297	0.11021	2.168921	0.007636	0.000718
1.52	2	2	1.892	0.80448	0.848689	3564.084	0.129013	2.53897	0.007071	0.000807
1.63	2	2	2.246	0.97322	1.026701	4771.313	0.172237	3.389603	0.00645	0.000976
1.718	2	2	2.533	1.108212	1.169112	5821.847	0.207279	4.079241	0.005986	0.001112
1.878	2	2	3.132	1.353652	1.428039	7909.834	0.280417	5.51859	0.005428	0.001358
1.98	2	2	3.526	1.51012	1.593106	9352.854	0.328525	6.46534	0.00511	0.001515
2.108	2	2	4.068	1.706472	1.800248	11279.1	0.394703	7.767722	0.004808	0.001712
2.322	2	2	4.948	2.034748	2.146564	14768.52	0.502151	9.88229	0.004302	0.002041
2.468	2	3	1.471	2.258712	2.382835	17330.59	0.568365	11.18538	0.003951	0.002266
2.634	2	3	1.548	2.513356	2.651473	20412.1	0.665239	13.09185	0.003735	0.002521
2.864	2	3	1.669	2.866176	3.023681	24962.41	0.817469	16.08773	0.00353	0.002875
3.127	2	3	1.811	3.269618	3.449294	30542.74	0.996119	19.60355	0.003305	0.003279
3.359	2	3	1.944	3.625506	3.824739	35780.91	1.163446	22.89654	0.003139	0.003636
3.607	2	3	2.098	4.005938	4.226077	41690.92	1.357194	26.70947	0.003	0.004018
3.77	2	3	2.204	4.25598	4.489859	45743.14	1.490552	29.33396	0.002919	0.004269
4.058	2	3	2.388	4.697772	4.955929	53215.36	1.722043	33.88967	0.002768	0.004712
4.298	2	3	2.572	5.065932	5.344321	59736.08	1.953533	38.44539	0.0027	0.005081
4.479	2	3	2.698	5.343586	5.637232	64824.39	2.112054	41.56506	0.002624	0.00536
4.838	2	3	2.972	5.894292	6.218201	75335.53	2.456773	48.34911	0.002508	0.005912
5.093	2	3	3.182	6.285462	6.630867	83128.74	2.720974	53.54857	0.002443	0.006304

250ppm PEO+250ppm PAM in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.107	1	2	1.192	0.170938	0.450397	953.5832	0.043543	1.815368	0.01795	0.000171
1.205	1	2	1.384	0.32127	0.8465	2478.179	0.066986	2.792742	0.007817	0.000322
1.308	1	2	1.747	0.479272	1.262813	4540.075	0.111309	4.640591	0.005837	0.000481
1.411	1	2	2.133	0.637274	1.679126	6988.149	0.158439	6.605522	0.004699	0.000639
1.525	1	2	2.609	0.81215	2.139899	10086.94	0.216559	9.028597	0.003955	0.000815
1.643	1	2	3.127	0.993162	2.61684	13678.03	0.279807	11.66547	0.003417	0.000996
1.73	1	2	3.522	1.12662	2.968482	16554.06	0.328036	13.67622	0.003113	0.00113
1.799	1	2	3.842	1.232466	3.247371	18964.05	0.367108	15.30518	0.002911	0.001236
1.965	1	2	4.681	1.48711	3.918322	25199.54	0.46955	19.5761	0.002558	0.001492
2.088	1	3	1.441	1.675792	4.415472	30193.51	0.530622	22.12226	0.002276	0.001681
2.2	1	3	1.502	1.8476	4.868161	35000.31	0.607366	25.32182	0.002143	0.001853
2.414	1	3	1.634	2.175876	5.733121	44830.86	0.773435	32.24544	0.001968	0.002182
2.641	1	3	1.774	2.524094	6.650626	56125.6	0.949569	39.58867	0.001795	0.002532
2.82	1	3	1.901	2.79868	7.374121	65620.94	1.109348	46.25004	0.001706	0.002807
3.082	1	3	2.084	3.200588	8.433091	80398.85	1.33958	55.84869	0.001575	0.00321
3.357	1	3	2.299	3.622438	9.544605	96970.11	1.610072	67.1258	0.001478	0.003633
3.702	1	3	2.614	4.151668	10.93905	119199.9	2.006373	83.64808	0.001402	0.004164
3.932	1	3	2.742	4.504488	11.86868	134862.7	2.16741	90.3619	0.001287	0.004518
4.099	1	3	2.907	4.760666	12.54367	146639.8	2.374997	99.01642	0.001262	0.004775

250ppm PEO +250ppm PAM in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	FR in vol
1.066	2	2	1.018	0.108044	0.113981	148.8599	0.022298	0.438819	0.06775	0.000108
1.168	2	2	1.112	0.264512	0.279048	577.209	0.033775	0.664693	0.017122	0.000265
1.257	2	2	1.254	0.401038	0.423076	1083.681	0.051113	1.005908	0.011272	0.000402
1.353	2	2	1.45	0.548302	0.578433	1739.803	0.075045	1.47688	0.008854	0.00055
1.537	2	2	1.934	0.830558	0.8762	3261.956	0.134141	2.639893	0.006897	0.000833
1.645	2	2	2.289	0.99623	1.050976	4295.729	0.177487	3.492929	0.006343	0.000999
1.838	2	2	2.993	1.292292	1.363307	6369.058	0.263445	5.184584	0.005595	0.001296
2.052	2	2	3.868	1.620568	1.709623	8971.645	0.370283	7.287138	0.005001	0.001625
2.113	2	2	4.13	1.714142	1.808339	9767.265	0.402273	7.916703	0.004856	0.001719
2.26	2	2	4.786	1.93964	2.046229	11776.45	0.482371	9.493017	0.004548	0.001945
2.376	2	3	1.437	2.117584	2.233952	13449.69	0.52559	10.34357	0.004157	0.002124
2.501	2	3	1.498	2.309334	2.436239	15335.34	0.602334	11.85388	0.004006	0.002316
2.751	2	3	1.622	2.692834	2.840813	19350.18	0.758338	14.92404	0.003709	0.002701
3.013	2	3	1.77	3.094742	3.264808	23885.2	0.944537	18.58842	0.003498	0.003104
3.191	2	3	1.869	3.367794	3.552865	27146.25	1.069089	21.03959	0.003343	0.003378
3.375	2	3	1.987	3.65005	3.850631	30663.04	1.217545	23.96119	0.003241	0.003661
3.565	2	3	2.101	3.94151	4.158108	34444.09	1.360968	26.78375	0.003107	0.003953
3.764	2	3	2.242	4.246776	4.480149	38561.19	1.53836	30.27481	0.003025	0.00426
4.021	2	3	2.413	4.641014	4.896052	44106.74	1.753495	34.50866	0.002888	0.004655
4.261	2	3	2.588	5.009174	5.284443	49509.18	1.973663	38.84154	0.00279	0.005024
4.411	2	3	2.692	5.239274	5.527188	52991.78	2.104505	41.4165	0.002719	0.005255
4.717	2	3	2.929	5.708678	6.022387	60340.92	2.402675	47.28446	0.002615	0.005726
5.089	2	3	3.219	6.279326	6.624394	69701.3	2.767524	54.46466	0.00249	0.006298

Total 1000ppm

1000ppm PAM in 1inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Volumetri
1.094	1	2	0.984	0.150996	0.397494	307.4061	0.018146	0.756545	0.009596	0.000151
1.167	1	2	1.27	0.262978	0.692284	727.3127	0.053067	2.212426	0.009251	0.000264
1.269	1	2	1.588	0.419446	1.104183	1501.205	0.091895	3.831203	0.006297	0.000421
1.374	1	2	1.833	0.580516	1.528197	2486.078	0.121809	5.078374	0.004358	0.000582
1.475	1	2	2.154	0.73545	1.936058	3589.104	0.161003	6.712422	0.003589	0.000738
1.542	1	2	2.346	0.838228	2.206619	4397.087	0.184447	7.689797	0.003165	0.000841
1.619	1	2	2.56	0.956346	2.517562	5395.516	0.210576	8.779163	0.002776	0.000959
1.683	1	2	2.769	1.054522	2.776009	6279.271	0.236095	9.843076	0.00256	0.001058
1.734	1	2	2.905	1.132756	2.981958	7017.021	0.252701	10.53538	0.002374	0.001136
1.78	1	2	3.054	1.20332	3.167717	7707.08	0.270893	11.29387	0.002256	0.001207
1.828	1	2	3.226	1.276952	3.361551	8451.357	0.291895	12.16943	0.002158	0.001281
1.86	1	2	3.299	1.32604	3.490775	8960.963	0.300808	12.54104	0.002062	0.00133
2.024	1	2	3.853	1.577616	4.153043	11734.37	0.368451	15.36117	0.001785	0.001582
2.168	1	2	4.395	1.798512	4.734548	14381.32	0.43463	18.12022	0.00162	0.001804
2.272	1	2	4.64	1.958048	5.154523	16409.32	0.464544	19.36739	0.001461	0.001964
2.521	1	3	1.453	2.340014	6.160041	21638.3	0.545719	22.75168	0.001202	0.002347
2.724	1	3	1.519	2.651416	6.979801	26269.07	0.628754	26.21349	0.001078	0.002659
2.97	1	3	1.626	3.02878	7.973204	32295.8	0.763371	31.82582	0.001003	0.003038
3.186	1	3	1.706	3.360124	8.845461	37942.94	0.864019	36.02196	0.000923	0.00337
3.427	1	3	1.828	3.729818	9.818673	44616.53	1.017507	42.42106	0.000882	0.003741
3.713	1	3	1.962	4.168542	10.97361	53022.69	1.186092	49.44959	0.000823	0.004181
3.895	1	3	2.097	4.44773	11.70856	58635.78	1.355936	56.53056	0.000826	0.004461
3.987	1	3	2.189	4.588858	12.08008	61548.88	1.471681	61.35612	0.000843	0.004603
4.164	1	3	2.205	4.860376	12.79485	67293.21	1.491811	62.19535	0.000761	0.004875

1000ppm PAM in 1.5inch pipe										
FR signa	Measure	Channel	PD signa	Flow rate	Velocity	Re	PD	S Stress	f	FR in Vol
1.138	2	2	1.097	0.218492	0.230291	161.7198	0.031944	0.62865	0.023755	0.0002191
1.221	2	2	1.16	0.345814	0.364489	329.8244	0.039636	0.780034	0.011766	0.0003469
1.351	2	2	1.511	0.545234	0.574678	668.6754	0.082493	1.623458	0.009851	0.0005469
1.499	2	2	1.9	0.772266	0.81397	1147.845	0.12999	2.558193	0.007738	0.0007746
1.594	2	2	2.142	0.917996	0.967569	1501.111	0.159538	3.1397	0.006721	0.0009208
1.735	2	2	2.552	1.13429	1.195544	2084.654	0.209599	4.124897	0.005783	0.0011377
1.865	2	2	3.005	1.33371	1.405733	2680.474	0.264911	5.213419	0.005287	0.0013377
2.062	2	2	3.556	1.635908	1.72425	3680.339	0.332188	6.537427	0.004407	0.0016408
2.157	2	2	3.843	1.781638	1.877849	4201.587	0.36723	7.227065	0.004107	0.001787
2.454	2	2	4.901	2.237236	2.358051	5982.931	0.496412	9.769353	0.003521	0.002244
2.653	2	3	1.461	2.542502	2.679801	7296.892	0.555784	10.93779	0.003052	0.0025502
2.892	2	3	1.553	2.909128	3.066226	8993.816	0.671529	13.21565	0.002817	0.0029179
3.23	2	3	1.694	3.42762	3.612717	11601.31	0.848921	16.70671	0.002565	0.0034379
3.486	2	3	1.806	3.820324	4.026628	13728.63	0.989829	19.47975	0.002408	0.0038318
3.823	2	3	1.966	4.337282	4.571503	16717.86	1.191125	23.44124	0.002248	0.0043503
4.138	2	3	2.114	4.820492	5.080807	19696.35	1.377323	27.10562	0.002104	0.004835
4.482	2	3	2.288	5.348188	5.636999	23142.68	1.596233	31.41374	0.001981	0.0053643
4.781	2	3	2.451	5.806854	6.120434	26295.44	1.801303	35.44951	0.001896	0.0058243
5.113	2	3	2.637	6.316142	6.657224	29960.75	2.03531	40.05474	0.001811	0.0063351

1000ppm PEO in 1inch pipe										
FR signa	Measure	Channel	PD signa	Flow rate	Velocity	Re	PD	S Stress	f	FR in Vol
1.126	1	2	1.374	0.200084	0.527775	2122.316	0.065765	2.741837	0.019766	0.000201
1.206	1	2	1.571	0.322804	0.851482	3933.107	0.089819	3.744665	0.010371	0.000324
1.315	1	2	1.901	0.49001	1.292532	6738.025	0.130112	5.424527	0.00652	0.000491
1.389	1	2	2.166	0.603526	1.591961	8815.521	0.162469	6.773508	0.005367	0.000605
1.51	1	2	2.756	0.78914	2.081567	12458.21	0.234508	9.776899	0.004531	0.000792
1.587	1	2	3.417	0.907258	2.393135	14913.77	0.315216	13.14172	0.004608	0.00091
1.657	1	2	4.002	1.014638	2.676378	17228.46	0.386644	16.11965	0.004519	0.001018
1.732	1	2	4.583	1.129688	2.979853	19788.47	0.457584	19.07723	0.004314	0.001133
1.906	1	3	1.518	1.396604	3.683915	26014.88	0.627496	26.16104	0.003871	0.001401
2.061	1	3	1.659	1.634374	4.311097	31863.03	0.804888	33.55673	0.003626	0.001639
2.241	1	3	1.829	1.910494	5.039437	38969.78	1.018765	42.47351	0.003358	0.001916
2.489	1	3	2.075	2.290926	6.042928	49254.8	1.328258	55.37663	0.003045	0.002298
2.638	1	3	2.222	2.519492	6.645832	55682.64	1.513198	63.08702	0.002868	0.002527
2.852	1	3	2.451	2.847768	7.511748	65211.82	1.801303	75.09846	0.002673	0.002856
3.031	1	3	2.657	3.122354	8.236041	73432.68	2.060472	85.9035	0.002543	0.003132
3.294	1	3	2.956	3.525796	9.300227	85893.17	2.436644	101.5866	0.002358	0.003536
3.514	1	3	3.21	3.863276	10.19042	96641.09	2.756201	114.9093	0.002222	0.003875
3.622	1	3	3.327	4.028948	10.62742	102019.3	2.903399	121.0461	0.002152	0.004041
3.854	1	3	3.62	4.384836	11.56617	113788.3	3.272022	136.4145	0.002048	0.004398

1000ppm PEO in 1.5inch pipe										
FR signa	Measure	Channel	PD signa	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.139	2	2	1.088	0.220026	0.231838	1016.651	0.030845	0.607023	0.022626	0.000221
1.214	2	2	1.178	0.335076	0.353065	1748.955	0.041834	0.823286	0.013232	0.000336
1.297	2	2	1.346	0.462398	0.487222	2649.636	0.062347	1.226976	0.010355	0.000464
1.403	2	2	1.588	0.625002	0.658555	3908.198	0.091895	1.808483	0.008354	0.000627
1.561	2	2	2.055	0.867374	0.913939	5964.133	0.148916	2.930646	0.007029	0.00087
1.689	2	2	2.545	1.063726	1.120832	7759.858	0.208745	4.108076	0.006551	0.001067
1.84	2	2	3.195	1.29536	1.364901	10004.84	0.28811	5.669973	0.006097	0.001299
2.088	2	2	4.446	1.675792	1.765757	13945.94	0.440857	8.676025	0.005575	0.001681
2.202	2	3	1.414	1.850668	1.950021	15850.72	0.496653	9.774102	0.00515	0.001856
2.267	2	3	1.453	1.950378	2.055084	16960.71	0.545719	10.73972	0.005095	0.001956
2.323	2	3	1.494	2.036282	2.1456	17930.31	0.597301	11.75485	0.005116	0.002042
2.477	2	3	1.595	2.272518	2.394518	20657.22	0.72437	14.25554	0.004981	0.002279
2.665	2	3	1.733	2.56091	2.698392	24098.82	0.897987	17.67232	0.004862	0.002569
2.888	2	3	1.918	2.902992	3.058839	28328.74	1.130736	22.2528	0.004765	0.002912
3.132	2	3	2.127	3.277288	3.453229	33125.27	1.393679	27.42749	0.004608	0.003287
3.396	2	3	2.369	3.682264	3.879946	38496.72	1.698139	33.41925	0.004447	0.003693
3.62	2	3	2.594	4.02588	4.242009	43191.49	1.981211	38.99009	0.004341	0.004038
3.975	2	3	2.949	4.57045	4.815814	50870.24	2.427837	47.77965	0.004127	0.004584
4.24	2	3	3.231	4.97696	5.244148	56779.7	2.782621	54.76178	0.003989	0.004992
4.443	2	3	3.446	5.288362	5.572268	61402.83	3.053113	60.08503	0.003877	0.005304
4.716	2	3	3.761	5.707144	6.013532	67745.08	3.449414	67.88421	0.003761	0.005724
4.895	2	3	3.952	5.98173	6.302859	71978.03	3.689711	72.61324	0.003662	0.006

900ppm PAM +100ppm PEO in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.082	1	2	1.147	0.132588	0.34893	266.6974	0.038049	1.586295	0.026102	0.000133
1.243	1	2	1.518	0.379562	0.998889	1373.462	0.083348	3.474868	0.006977	0.000381
1.322	1	2	1.749	0.500748	1.317813	2115.13	0.111553	4.650772	0.005365	0.000502
1.4	1	2	1.981	0.6204	1.6327	2953.527	0.13988	5.831767	0.004383	0.000622
1.479	1	2	2.198	0.741586	1.951624	3900.256	0.166376	6.936404	0.003648	0.000744
1.57	1	2	2.478	0.88118	2.318992	5102.872	0.200564	8.361742	0.003115	0.000884
1.631	1	2	2.67	0.974754	2.56525	5971.942	0.224007	9.339117	0.002843	0.000978
1.702	1	2	2.887	1.083668	2.851878	7043.675	0.250503	10.44375	0.002573	0.001087
1.764	1	2	3.093	1.178776	3.102172	8030.301	0.275655	11.4924	0.002392	0.001182
1.838	1	2	3.328	1.292292	3.400911	9267.312	0.304349	12.68866	0.002198	0.001296
1.969	1	2	3.78	1.493246	3.92976	11608.32	0.359538	14.98956	0.001945	0.001498
2.139	1	2	4.313	1.754026	4.616052	14917.7	0.424617	17.7028	0.001664	0.001759
2.293	1	2	4.843	1.990262	5.237752	18164.03	0.48933	20.40076	0.00149	0.001996
2.47	1	3	1.446	2.26178	5.952303	22169.73	0.536913	22.38452	0.001266	0.002269
2.733	1	3	1.551	2.665222	7.014037	28631.28	0.669013	27.89195	0.001136	0.002673
3.043	1	3	1.693	3.140762	8.26551	36978.57	0.847663	35.34009	0.001036	0.00315
3.306	1	3	1.798	3.544204	9.327244	44641.16	0.979764	40.84751	0.000941	0.003555
3.616	1	3	1.948	4.019744	10.57872	54317.88	1.168479	48.71526	0.000872	0.004032
3.87	1	3	2.075	4.40938	11.60412	62741.36	1.328258	55.37663	0.000824	0.004423
3.948	1	3	2.145	4.529032	11.91901	65414.44	1.416325	59.04825	0.000833	0.004543
4.018	1	3	2.19	4.636412	12.2016	67847.2	1.472939	61.40857	0.000826	0.00465
4.146	1	3	2.312	4.832764	12.71833	72377.31	1.626427	67.80768	0.00084	0.004847

900ppm PAM +100ppm PEO in 1.5inch										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in Vol
1.133	2	2	1.098	0.210822	0.22214	161.5141	0.032066	0.631053	0.02562	0.000211
1.205	2	2	1.158	0.32127	0.338517	311.3924	0.039392	0.775228	0.013553	0.000322
1.304	2	2	1.402	0.473136	0.498536	569.2235	0.069184	1.36154	0.010975	0.000475
1.419	2	2	1.619	0.649546	0.684417	932.7005	0.09568	1.882973	0.008053	0.000652
1.484	2	2	1.857	0.749256	0.78948	1165.168	0.12474	2.454868	0.007891	0.000752
1.645	2	2	2.312	0.99623	1.049713	1816.335	0.180295	3.548196	0.006451	0.000999
1.758	2	2	2.659	1.169572	1.23236	2332.161	0.222664	4.382009	0.005781	0.001173
1.869	2	2	3.026	1.339846	1.411776	2882.317	0.267475	5.26388	0.005291	0.001344
1.94	2	2	3.247	1.44876	1.526537	3255.614	0.294459	5.794925	0.004982	0.001453
2.126	2	2	3.879	1.734084	1.827178	4308.193	0.371626	7.31357	0.004389	0.001739
2.286	2	2	4.455	1.979524	2.085795	5295.206	0.441956	8.697651	0.004005	0.001985
2.398	2	3	1.386	2.151332	2.266826	6028.513	0.461427	9.080841	0.00354	0.002158
2.578	2	3	1.458	2.427452	2.55777	7276.666	0.55201	10.86351	0.003327	0.002435
2.701	2	3	1.504	2.616134	2.756581	8176.957	0.609882	12.00244	0.003164	0.002624
2.873	2	3	1.578	2.879982	3.034594	9497.718	0.702982	13.83463	0.00301	0.002889
3.061	2	3	1.658	3.168374	3.338468	11020.61	0.80363	15.81537	0.002843	0.003178
3.342	2	3	1.781	3.599428	3.792663	13444.07	0.958376	18.86077	0.002627	0.00361
3.537	2	3	1.872	3.898558	4.107852	15225.02	1.072863	21.11387	0.002507	0.00391
3.748	2	3	1.973	4.222232	4.448902	17239.89	1.199931	23.61456	0.00239	0.004235
3.972	2	3	2.097	4.565848	4.810965	19475.31	1.355936	26.68471	0.00231	0.00458
4.156	2	3	2.182	4.848104	5.108374	21383.51	1.462874	28.78925	0.00221	0.004863
4.417	2	3	2.324	5.248478	5.530242	24198.04	1.641524	32.30508	0.002116	0.005264
4.695	2	3	2.482	5.67493	5.979588	27330.58	1.840304	36.21705	0.002029	0.005692
5.108	2	3	2.737	6.308472	6.647142	32231.02	2.16112	42.53067	0.001928	0.006327

900ppm PEO +100ppm PAM in 1 inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.137	1	2	1.238	0.216958	0.570966	1557.793	0.04916	2.04953	0.012595	0.000218
1.228	1	2	1.494	0.356552	0.938334	3134.852	0.080417	3.352697	0.007629	0.000358
1.337	1	2	1.954	0.523758	1.378368	5386.589	0.136583	5.694324	0.006005	0.000525
1.455	1	2	2.414	0.70477	1.854736	8180.691	0.192749	8.035951	0.00468	0.000707
1.511	1	2	2.821	0.790674	2.080808	9618.44	0.242444	10.10778	0.004677	0.000793
1.578	1	2	3.149	0.893452	2.351288	11423.96	0.282493	11.77746	0.004268	0.000896
1.685	1	2	3.761	1.05759	2.783248	14485.22	0.357218	14.89285	0.003852	0.001061
1.751	1	2	4.181	1.158834	3.049691	16474.65	0.4085	17.03085	0.003669	0.001162
1.846	1	2	4.757	1.304564	3.433207	19464.1	0.47883	19.96298	0.003393	0.001308
1.97	1	3	1.456	1.49478	3.933797	23574.69	0.549494	22.90904	0.002966	0.001499
2.115	1	3	1.562	1.71721	4.519163	28658.57	0.682852	28.46892	0.002793	0.001722
2.315	1	3	1.708	2.02401	5.326566	36120.12	0.866535	36.12686	0.002551	0.00203
2.462	1	3	1.825	2.249508	5.920007	41910.93	1.013733	42.26371	0.002416	0.002256
2.637	1	3	1.968	2.517958	6.626484	49119.01	1.193641	49.7643	0.00227	0.002526
2.885	1	3	2.176	2.89839	7.627662	59878.62	1.455326	60.67425	0.002089	0.002907
3.055	1	3	2.342	3.15917	8.313954	67599.35	1.66417	69.38123	0.002011	0.003169
3.27	1	3	2.556	3.48898	9.181912	77741.03	1.933404	80.60588	0.001915	0.003499
3.536	1	3	2.822	3.897024	10.25576	90838.21	2.268058	94.55803	0.001801	0.003909
3.671	1	3	2.952	4.104114	10.80075	97706.31	2.431611	101.3767	0.001741	0.004116
3.723	1	3	3.005	4.183882	11.01068	100390.1	2.498291	104.1567	0.001721	0.004196
3.793	1	3	3.089	4.291262	11.29327	104036	2.603971	108.5626	0.001705	0.004304
3.967	1	3	3.28	4.558178	11.99571	113259.4	2.844268	118.5809	0.001651	0.004572

900ppm PEO +100ppm PAM in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.104	2	2	1.089	0.166336	0.175266	387.4435	0.030967	0.609426	0.039746	0.000167
1.228	2	2	1.219	0.356552	0.375693	1133.312	0.04684	0.921806	0.013084	0.000358
1.34	2	2	1.44	0.52836	0.556725	1971.489	0.073824	1.452851	0.009391	0.00053
1.426	2	2	1.671	0.660284	0.695731	2698.118	0.102029	2.007925	0.008311	0.000662
1.532	2	2	1.979	0.822888	0.867065	3678.334	0.139636	2.748024	0.007323	0.000825
1.657	2	2	2.434	1.014638	1.069109	4939.809	0.195191	3.841352	0.006733	0.001018
1.81	2	2	3.031	1.24934	1.316411	6620.996	0.268085	5.275895	0.006099	0.001253
1.914	2	2	3.505	1.408876	1.484511	7841.41	0.325961	6.414878	0.005832	0.001413
2.081	2	2	4.318	1.665054	1.754442	9920.433	0.425228	8.368451	0.005447	0.00167
2.234	2	3	1.413	1.899756	2.001744	11943.98	0.495395	9.749342	0.004874	0.001905
2.425	2	3	1.523	2.19275	2.310468	14616.26	0.633786	12.47287	0.004681	0.002199
2.568	2	3	1.607	2.412112	2.541606	16715.79	0.739467	14.55265	0.004513	0.002419
2.765	2	3	1.73	2.71431	2.860028	19737.33	0.894213	17.59804	0.00431	0.002722
2.974	2	3	1.867	3.034916	3.197845	23096.38	1.066573	20.99007	0.004112	0.003044
3.17	2	3	2.004	3.33558	3.514651	26381.19	1.238932	24.3821	0.003954	0.003346
3.373	2	3	2.153	3.646982	3.84277	29913	1.426389	28.07123	0.003808	0.003658
3.555	2	3	2.295	3.92617	4.136946	33186.11	1.60504	31.58706	0.003698	0.003938
3.789	2	3	2.485	4.285126	4.515173	37535.41	1.844079	36.29133	0.003566	0.004298
3.99	2	3	2.652	4.59346	4.84006	41392.38	2.054181	40.42613	0.003457	0.004607
4.175	2	3	2.814	4.87725	5.139085	45037.05	2.257993	44.43714	0.003371	0.004892
4.446	2	3	3.05	5.292964	5.577117	50533.22	2.554905	50.28034	0.003239	0.005309
4.631	2	3	3.234	5.576754	5.876142	54388.52	2.786395	54.83605	0.003182	0.005594
4.818	2	3	3.402	5.863612	6.1784	58367.65	2.997756	58.99562	0.003096	0.005881

800ppm PAM +200ppm PEO in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.086	1	2	0.984	0.138724	0.365078	298.5705	0.018146	0.756545	0.011372	0.000139
1.165	1	2	1.16	0.25991	0.684002	806.9549	0.039636	1.652472	0.007076	0.000261
1.297	1	2	1.539	0.462398	1.216888	2009.346	0.085912	3.581769	0.004846	0.000464
1.393	1	2	1.799	0.609662	1.604441	3113.169	0.117658	4.905297	0.003818	0.000611
1.494	1	2	2.125	0.764596	2.012179	4455.932	0.157463	6.564798	0.003248	0.000767
1.58	1	2	2.364	0.89652	2.359362	5733.365	0.186644	7.781426	0.002801	0.000899
1.68	1	2	2.69	1.04992	2.763063	7362.724	0.226449	9.440927	0.002477	0.001053
1.78	1	2	3.003	1.20332	3.166765	9137.495	0.264666	11.03425	0.002204	0.001207
1.836	1	2	3.218	1.289224	3.392837	10191.82	0.290918	12.12871	0.002111	0.001293
2.052	1	2	3.862	1.620568	4.264832	14640.79	0.36955	15.40699	0.001697	0.001625
2.197	1	2	4.44	1.842998	4.850198	17948.19	0.440124	18.34929	0.001563	0.001849
2.326	1	2	4.878	2.040884	5.370973	21094.24	0.493604	20.57893	0.001429	0.002047
2.475	1	3	1.438	2.26945	5.972488	24955.8	0.526848	21.96491	0.001234	0.002276
2.595	1	3	1.494	2.45353	6.456929	28236.39	0.597301	24.9022	0.001197	0.002461
2.763	1	3	1.556	2.711242	7.135147	33075.08	0.675304	28.15421	0.001108	0.002719
2.952	1	3	1.645	3.001168	7.898142	38848.34	0.787275	32.82241	0.001054	0.00301
3.163	1	3	1.718	3.324842	8.749952	45689.05	0.879116	36.65138	0.000959	0.003335
3.416	1	3	1.821	3.712944	9.771316	54417.88	1.0087	42.0539	0.000882	0.003724
3.744	1	3	2.034	4.216096	11.09546	66549.35	1.276675	53.22611	0.000866	0.004229
3.908	1	3	2.105	4.467672	11.75753	72946.47	1.366001	56.95018	0.000825	0.004481
4.141	1	3	2.269	4.825094	12.69815	82401.54	1.572329	65.55225	0.000814	0.00484

800ppm PAM +200ppm PEO in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.161	2	2	1.12	0.253774	0.267398	220.6296	0.034752	0.683917	0.019163	0.000255
1.255	2	2	1.255	0.39797	0.419335	449.8878	0.051236	1.008311	0.011488	0.000399
1.367	2	2	1.543	0.569778	0.600367	794.176	0.0864	1.700351	0.009451	0.000571
1.504	2	2	1.902	0.779936	0.821807	1305.707	0.130234	2.562999	0.007603	0.000782
1.637	2	2	2.304	0.983958	1.036782	1886.509	0.179318	3.528973	0.006577	0.000987
1.728	2	2	2.565	1.123552	1.18387	2327.559	0.211187	4.156135	0.005941	0.001127
1.861	2	2	2.988	1.327574	1.398845	3031.497	0.262835	5.172569	0.005296	0.001332
1.973	2	2	3.345	1.499382	1.579876	3675.835	0.306425	6.030411	0.00484	0.001504
2.126	2	2	3.87	1.734084	1.827178	4627.78	0.370527	7.291944	0.004376	0.001739
2.323	2	2	4.54	2.036282	2.1456	5968.387	0.452334	8.901899	0.003874	0.002042
2.452	2	3	1.402	2.234168	2.354109	6912.595	0.481556	9.47699	0.003426	0.002241
2.56	2	3	1.444	2.39984	2.528675	7741.728	0.534396	10.51688	0.003295	0.002407
2.714	2	3	1.506	2.636076	2.777594	8982.769	0.612399	12.05196	0.00313	0.002644
3.021	2	3	1.631	3.107014	3.273814	11653.49	0.769661	15.14687	0.002831	0.003116
3.223	2	3	1.717	3.416882	3.600317	13546.83	0.877858	17.27617	0.00267	0.003427
3.491	2	3	1.846	3.827994	4.0335	16217.15	1.040153	20.47013	0.002521	0.00384
3.836	2	3	2.023	4.357224	4.591141	19908.29	1.262836	24.85252	0.002362	0.00437
4.157	2	3	2.187	4.849638	5.109991	23586.88	1.469165	28.91305	0.002218	0.004864
4.395	2	3	2.301	5.21473	5.494683	26459.98	1.612588	31.73561	0.002106	0.00523
4.692	2	3	2.487	5.670328	5.974739	30213.09	1.846595	36.34085	0.00204	0.005687
5.104	2	3	2.729	6.302336	6.640677	35716.75	2.151055	42.3326	0.001923	0.006321

800ppm PEO +200ppm PAM in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.115	1	2	1.189	0.18321	0.482152	917.3296	0.043177	1.800096	0.015513	0.000184
1.201	1	2	1.418	0.315134	0.829335	2026.637	0.071138	2.965819	0.008639	0.000316
1.32	1	2	1.853	0.49768	1.309739	3952.008	0.124251	5.180184	0.00605	0.000499
1.42	1	2	2.282	0.65108	1.71344	5852.64	0.176632	7.364006	0.005025	0.000653
1.541	1	2	2.833	0.836694	2.201919	8444.158	0.243909	10.16887	0.004202	0.000839
1.583	1	2	3.062	0.901122	2.371473	9411.122	0.27187	11.33459	0.004038	0.000904
1.686	1	2	3.568	1.059124	2.787285	11917.49	0.333653	13.91038	0.003587	0.001062
1.765	1	2	3.989	1.18031	3.106209	13961.99	0.385057	16.05348	0.003333	0.001184
1.9	1	2	4.768	1.3874	3.651206	17682.88	0.480173	20.01897	0.003008	0.001392
2.009	1	3	1.445	1.554606	4.09124	20882.3	0.535655	22.33207	0.002673	0.001559
2.211	1	3	1.573	1.864474	4.906717	27235.99	0.696691	29.04589	0.002417	0.00187
2.318	1	3	1.645	2.028612	5.338677	30810.34	0.787275	32.82241	0.002307	0.002035
2.566	1	3	1.828	2.409044	6.339856	39608.76	1.017507	42.42106	0.002114	0.002416
2.737	1	3	1.954	2.671358	7.030185	46067.44	1.176027	49.02997	0.001987	0.002679
2.985	1	3	2.161	3.05179	8.031364	55963.1	1.436454	59.88747	0.00186	0.003061
3.207	1	3	2.345	3.392338	8.92758	65320.52	1.667945	69.53858	0.001748	0.003403
3.49	1	3	2.58	3.82646	10.07005	77890.28	1.963598	81.86473	0.001617	0.003838
3.757	1	3	2.837	4.236038	11.14794	90370.56	2.28693	95.34481	0.001537	0.004249
3.827	1	3	2.911	4.343418	11.43053	93738.09	2.380029	99.22623	0.001521	0.004356
4.009	1	3	3.093	4.622606	12.16526	102673.3	2.609003	108.7724	0.001472	0.004637

800ppm PEO+200ppm PAM in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.069	2	2	1.068	0.112646	0.118693	151.3073	0.028403	0.558965	0.079488	0.000113
1.248	2	2	1.283	0.387232	0.408021	919.5965	0.054654	1.075593	0.012944	0.000388
1.373	2	2	1.525	0.578982	0.610065	1655.436	0.084203	1.657099	0.00892	0.000581
1.494	2	2	1.854	0.764596	0.805643	2485.497	0.124373	2.447659	0.007555	0.000767
1.573	2	2	2.105	0.885782	0.933335	3081.737	0.155021	3.050792	0.007016	0.000888
1.739	2	2	2.708	1.140426	1.20165	4458.419	0.228647	4.499752	0.006243	0.001144
1.887	2	2	3.318	1.367458	1.44087	5813.205	0.303128	5.965532	0.005757	0.001372
2.084	2	2	4.198	1.669656	1.759291	7782.994	0.410576	8.080101	0.00523	0.001675
2.239	2	2	4.962	1.907426	2.009826	9454.785	0.50386	9.915931	0.004918	0.001913
2.32	2	3	1.436	2.03168	2.140751	10368.31	0.524332	10.31881	0.004511	0.002038
2.49	2	3	1.528	2.29246	2.415531	12369.68	0.640077	12.59666	0.004325	0.002299
2.69	2	3	1.641	2.59926	2.738801	14862.1	0.782242	15.39447	0.004112	0.002607
2.927	2	3	1.78	2.962818	3.121877	17995.92	0.957118	18.83601	0.003872	0.002972
3.162	2	3	1.927	3.323308	3.50172	21283.98	1.142059	22.47563	0.003672	0.003333
3.387	2	3	2.074	3.668458	3.865399	24590.65	1.326999	26.11525	0.003502	0.003679
3.598	2	3	2.226	3.992132	4.206449	27825.2	1.518231	29.87866	0.003383	0.004004
3.843	2	3	2.401	4.367962	4.602456	31735.47	1.738398	34.21154	0.003236	0.004381
4.138	2	3	2.629	4.820492	5.07928	36653.49	2.025245	39.85667	0.003095	0.004835
4.403	2	3	2.841	5.227002	5.507613	41257.57	2.291962	45.10564	0.002979	0.005243
4.648	2	3	3.04	5.602832	5.90362	45664.12	2.542324	50.03275	0.002876	0.00562
4.849	2	3	3.224	5.911166	6.228507	49383.02	2.773814	54.58846	0.002819	0.005929
5.026	2	3	3.374	6.182684	6.514601	52733.02	2.962529	58.30236	0.002752	0.006201

600ppm PAM+400ppm PEO in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in Vol
1.146	1	2	1.161	0.230764	0.607299	749.7895	0.039758	1.657562	0.009004	0.000231
1.237	1	2	1.414	0.370358	0.974667	1551.466	0.070649	2.945457	0.006212	0.000371
1.334	1	2	1.807	0.519156	1.366257	2607.343	0.118635	4.946021	0.005308	0.000521
1.459	1	2	2.191	0.710906	1.870884	4227.019	0.165521	6.900771	0.00395	0.000713
1.568	1	2	2.563	0.878112	2.310918	5848.497	0.210942	8.794434	0.003299	0.000881
1.629	1	2	2.764	0.971686	2.557176	6833.447	0.235484	9.817623	0.003008	0.000975
1.728	1	2	3.088	1.123552	2.95684	8542.412	0.275045	11.46694	0.002628	0.001127
1.827	1	2	3.435	1.275418	3.356504	10380.36	0.317414	13.23334	0.002353	0.001279
1.934	1	2	3.86	1.439556	3.788464	12503.36	0.369306	15.3968	0.002149	0.001444
2.016	1	2	4.142	1.565344	4.119499	14221.6	0.403738	16.83232	0.001987	0.00157
2.138	1	2	4.635	1.752492	4.612015	16917.55	0.463934	19.34194	0.001822	0.001758
2.347	1	3	1.45	2.073098	5.45575	21902.32	0.541945	22.59433	0.001521	0.002079
2.5	1	3	1.511	2.3078	6.073413	25827.69	0.618689	25.79388	0.001401	0.002315
2.844	1	3	1.673	2.835496	7.462145	35444.58	0.822501	34.29105	0.001234	0.002844
3.082	1	3	1.79	3.200588	8.422954	42697.5	0.969699	40.4279	0.001142	0.00321
3.272	1	3	1.88	3.492048	9.189986	48818.26	1.082928	45.14855	0.001071	0.003503
3.664	1	3	2.125	4.093376	10.77249	62322.43	1.391163	57.99921	0.001001	0.004106
3.902	1	3	2.246	4.458468	11.7333	71068.47	1.543393	64.34586	0.000936	0.004472
4.138	1	3	2.414	4.820492	12.68604	80129.69	1.754753	73.15775	0.000911	0.004835

600ppm PAM +400ppm PEO in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in Vol
1.129	2	2	1.069	0.204686	0.215675	188.7384	0.028525	0.561368	0.024178	0.000205
1.221	2	2	1.226	0.345814	0.364379	422.6118	0.047695	0.938626	0.014163	0.000347
1.286	2	2	1.368	0.445524	0.469442	623.8303	0.065033	1.279841	0.011635	0.000447
1.364	2	2	1.54	0.565176	0.595517	899.2248	0.086034	1.693143	0.009565	0.000567
1.453	2	2	1.761	0.701702	0.739373	1254.03	0.113018	2.224188	0.008151	0.000704
1.565	2	2	2.087	0.87351	0.920404	1755.94	0.152823	3.007539	0.007113	0.000876
1.698	2	2	2.496	1.077532	1.135379	2424.572	0.202762	3.990333	0.006201	0.001081
1.821	2	2	2.931	1.266214	1.334191	3107.065	0.255875	5.035603	0.005667	0.00127
1.991	2	2	3.513	1.526994	1.608971	4143.459	0.326937	6.434102	0.004979	0.001532
2.122	2	2	4.013	1.727948	1.820713	5010.662	0.387987	7.635561	0.004615	0.001733
2.309	2	2	4.806	2.014806	2.122971	6344.883	0.484813	9.541076	0.004241	0.002021
2.442	2	3	1.429	2.218828	2.337946	7358.907	0.515525	10.14549	0.003719	0.002226
2.598	2	3	1.496	2.458132	2.590097	8613.625	0.599818	11.80437	0.003525	0.002466
2.751	2	3	1.562	2.692834	2.837399	9909.731	0.682852	13.43848	0.003344	0.002701
2.938	2	3	1.645	2.979692	3.139657	11578.05	0.787275	15.4935	0.003149	0.002989
3.2	2	3	1.77	3.3816	3.563141	14063.73	0.944537	18.58842	0.002933	0.003392
3.572	2	3	1.961	3.952248	4.164424	17872.94	1.184834	23.31745	0.002694	0.003964
3.822	2	3	2.095	4.335748	4.568512	20607.14	1.35342	26.63519	0.002557	0.004349
4.179	2	3	2.305	4.883386	5.14555	24741.15	1.617621	31.83465	0.002409	0.004898
4.42	2	3	2.434	5.25308	5.535091	27678.02	1.779915	35.0286	0.002291	0.005269
4.633	2	3	2.57	5.579822	5.879375	30368.04	1.951017	38.39587	0.002225	0.005597
4.784	2	3	2.672	5.811456	6.123444	32327.28	2.079343	40.92132	0.002186	0.005829
5.101	2	3	2.888	6.297734	6.635828	36577.41	2.351093	46.26933	0.002105	0.006317

600ppm PEO+400ppm PAM in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in Vol
1.116	1	2	1.298	0.184744	0.486189	663.8463	0.056486	2.35496	0.019959	0.000185
1.228	1	2	1.494	0.356552	0.938334	1847.147	0.080417	3.352697	0.007629	0.000358
1.317	1	2	1.801	0.493078	1.297628	3059.365	0.117902	4.915478	0.005848	0.000495
1.371	1	2	2.005	0.575914	1.515627	3895.813	0.142811	5.953939	0.005193	0.000578
1.467	1	2	2.375	0.723178	1.90318	5552.732	0.187988	7.837421	0.004335	0.000725
1.562	1	2	2.722	0.868908	2.286696	7389.18	0.230356	9.603823	0.00368	0.000872
1.643	1	2	3.042	0.993162	2.613694	9097.866	0.269428	11.23278	0.003294	0.000996
1.727	1	2	3.388	1.122018	2.952803	11000.11	0.311675	12.99409	0.002986	0.001125
1.803	1	2	3.723	1.238602	3.259616	12829.7	0.352578	14.69941	0.002772	0.001242
2.038	1	2	4.757	1.599092	4.208314	19093.52	0.47883	19.96298	0.002258	0.001604
2.204	1	3	1.455	1.853736	4.878458	24030.74	0.548236	22.85659	0.001924	0.001859
2.422	1	3	1.57	2.188148	5.758526	31108.05	0.692917	28.88853	0.001745	0.002195
2.589	1	3	1.658	2.444326	6.432707	36957.99	0.80363	33.50428	0.001622	0.002452
2.817	1	3	1.788	2.794078	7.353146	45509.61	0.967183	40.323	0.001494	0.002802
2.908	1	3	1.904	2.933672	7.720514	49097.21	1.113122	46.40739	0.00156	0.002942
3.26	1	3	2.064	3.47364	9.141542	63863.83	1.314418	54.79966	0.001314	0.003484
3.486	1	3	2.239	3.820324	10.05391	74055.65	1.534586	63.9787	0.001268	0.003832
3.686	1	3	2.359	4.127124	10.86131	83516.3	1.685558	70.2729	0.001193	0.00414
3.843	1	3	2.487	4.367962	11.49512	91223.65	1.846595	76.98672	0.001167	0.004381
4.098	1	3	2.679	4.759132	12.52456	104251.3	2.08815	87.05744	0.001112	0.004773

600ppm PEO+400ppm PAM in 1.5inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.141	2	2	1.088	0.223094	0.235071	262.4392	0.030845	0.607023	0.022008	0.000224
1.221	2	2	1.212	0.345814	0.364379	519.1546	0.045985	0.904985	0.013655	0.000347
1.334	2	2	1.455	0.519156	0.547027	977.0836	0.075656	1.488895	0.009968	0.000521
1.416	2	2	1.666	0.644944	0.679568	1369.563	0.101419	1.99591	0.008659	0.000647
1.524	2	2	1.964	0.810616	0.854134	1954.889	0.137804	2.71198	0.007447	0.000813
1.697	2	2	2.536	1.075998	1.133763	3037.76	0.207646	4.08645	0.006369	0.001079
1.863	2	2	3.164	1.330642	1.402077	4227.961	0.284324	5.595483	0.005702	0.001335
1.968	2	2	3.548	1.491712	1.571795	5050.861	0.331211	6.518204	0.005286	0.001496
2.108	2	2	4.141	1.706472	1.798084	6227.034	0.403616	7.943135	0.004922	0.001712
2.25	2	2	4.719	1.9243	2.027606	7507.309	0.47419	9.332022	0.004548	0.00193
2.408	2	3	1.447	2.166672	2.28299	9029.644	0.538171	10.59116	0.004071	0.002173
2.601	2	3	1.537	2.462734	2.594946	11021.59	0.6514	12.8195	0.003814	0.00247
2.771	2	3	1.619	2.723514	2.869726	12890.74	0.754564	14.84976	0.003612	0.002732
3.075	2	3	1.768	3.18985	3.361097	16485.8	0.942021	18.5389	0.003288	0.003199
3.328	2	3	1.912	3.577952	3.770034	19711.46	1.123187	22.10424	0.003116	0.003589
3.589	2	3	2.06	3.978326	4.191902	23249.62	1.309386	25.76862	0.002938	0.00399
3.819	2	3	2.2	4.331146	4.563663	26536.93	1.48552	29.23492	0.002812	0.004344
4.004	2	3	2.314	4.614936	4.862689	29292.04	1.628943	32.05748	0.002716	0.004629
4.139	2	3	2.404	4.822026	5.080896	31363.22	1.742172	34.28582	0.002661	0.004837
4.462	2	3	2.624	5.317508	5.602978	36520.3	2.018954	39.73287	0.002536	0.005334
4.704	2	3	2.787	5.688736	5.994136	40564.74	2.224025	43.76864	0.002441	0.005706
4.933	2	3	2.942	6.040022	6.36428	44529.77	2.41903	47.60633	0.002355	0.006058
5.073	2	3	3.056	6.254782	6.59057	47018.28	2.562454	50.4289	0.002326	0.006274

500ppm PEO+500ppm PAM in 1inch pipe										
FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.123	1	2	1.215	0.195482	0.514448	667.7036	0.046352	1.932449	0.014628	0.000196
1.187	1	2	1.369	0.293658	0.772817	1269.494	0.065155	2.716385	0.009112	0.000295
1.263	1	2	1.614	0.410242	1.07963	2152.208	0.095069	3.963556	0.006812	0.000411
1.363	1	2	1.966	0.563642	1.483331	3553.975	0.138049	5.75541	0.00524	0.000565
1.468	1	2	2.332	0.724712	1.907217	5285.31	0.182737	7.61853	0.004196	0.000727
1.599	1	2	2.816	0.925666	2.436065	7778.394	0.241834	10.08233	0.003404	0.000928
1.723	1	2	3.344	1.115882	2.936655	10448.16	0.306302	12.77011	0.002967	0.001119
1.808	1	2	3.676	1.246272	3.279801	12439.94	0.34684	14.46015	0.002693	0.00125
2.015	1	2	4.601	1.56381	4.115462	17801.32	0.459782	19.16886	0.002267	0.001569
2.16	1	3	1.429	1.78624	4.700829	21960.54	0.515525	21.49284	0.001949	0.001792
2.328	1	3	1.511	2.043952	5.379047	27167.98	0.618689	25.79388	0.001786	0.00205
2.484	1	3	1.598	2.283256	6.008821	32357.66	0.728144	30.35718	0.001684	0.00229
2.584	1	3	1.662	2.436656	6.412522	35856.23	0.808662	33.71408	0.001643	0.002444
2.79	1	3	1.775	2.75266	7.244146	43469.09	0.950828	39.64112	0.001513	0.002761
3.073	1	3	1.935	3.186782	8.386621	54777	1.152124	48.03339	0.001368	0.003196
3.318	1	3	2.104	3.562612	9.375688	65319.45	1.364742	56.89773	0.001297	0.003573
3.524	1	3	2.242	3.878616	10.20731	74699.38	1.53836	64.13606	0.001233	0.00389
3.773	1	3	2.418	4.260582	11.21253	86641.05	1.759786	73.36755	0.001169	0.004273
3.891	1	3	2.503	4.441594	11.6889	92523.98	1.866724	77.82595	0.001141	0.004455
4.114	1	3	2.653	4.783676	12.58915	104023.4	2.055439	85.6937	0.001083	0.004798

FR signal	Measure	Channel	PD signal	Flow rate	Velocity	Re	PD	S Stress	f	Fr in vol
1.147	2	2	1.095	0.232298	0.244769	250.5836	0.0317	0.623844	0.020861	0.000233
1.264	2	2	1.286	0.411776	0.433882	618.7166	0.055021	1.082801	0.011523	0.000413
1.374	2	2	1.542	0.580516	0.611681	1064.118	0.086278	1.697949	0.009092	0.000582
1.472	2	2	1.815	0.730848	0.770084	1530.735	0.119612	2.353945	0.007952	0.000733
1.614	2	2	2.248	0.948676	0.999606	2310.867	0.172481	3.394409	0.006806	0.000952
1.751	2	2	2.748	1.158834	1.221046	3169.469	0.233531	4.595869	0.006176	0.001162
1.873	2	2	3.226	1.345982	1.418241	4014.611	0.291895	5.744464	0.005722	0.00135
1.944	2	2	3.512	1.454896	1.533002	4539.404	0.326815	6.431699	0.005483	0.001459
2.104	2	2	4.202	1.700336	1.791618	5806.237	0.411064	8.089713	0.005049	0.001705
2.277	2	2	4.977	1.965718	2.071248	7300.357	0.505692	9.951975	0.004647	0.001972
2.433	2	3	1.474	2.205022	2.323399	8752.218	0.572139	11.25966	0.004179	0.002212
2.629	2	3	1.567	2.505686	2.640204	10709.49	0.689143	13.56228	0.003898	0.002513
2.781	2	3	1.649	2.738854	2.885889	12324.83	0.792307	15.59254	0.003751	0.002747
2.99	2	3	1.76	3.05946	3.223707	14678.71	0.931956	18.34082	0.003536	0.003069
3.19	2	3	1.872	3.36626	3.546978	17069.35	1.072863	21.11387	0.003362	0.003376
3.418	2	3	2.006	3.716012	3.915506	19952.54	1.241449	24.43162	0.003193	0.003727
3.661	2	3	2.153	4.088774	4.30828	23203.2	1.426389	28.07123	0.00303	0.004101
3.804	2	3	2.246	4.308136	4.539418	25198.98	1.543393	30.37385	0.002953	0.004321
4.06	2	3	2.411	4.70084	4.953204	28920.2	1.750979	34.45914	0.002814	0.004715
4.345	2	3	2.601	5.13803	5.413865	33279.76	1.990018	39.16341	0.002677	0.005153
4.6	2	3	2.783	5.5292	5.826035	37367.41	2.218992	43.6696	0.002578	0.005546
5.084	2	3	3.144	6.271656	6.60835	45592.17	2.673166	52.60771	0.002413	0.006291

Appendix D
Calculation Sample

Taking one data from a solution containing 400ppm PAM and 100ppm PEO in 1inch pipeline from polymer-polymer studies (total 500ppm polymer concentration) as an example. The flow rate signal reads 3.114, and the pressure drop signal is 1.653.

Flow rate transducer equation is,

$$Mass\ flow\ (KgS^{-1}) = 1.534 * \text{(signal reading)} - 1.5272$$

And pressure transducer output equation is,

RANGE	DIFFERENTIAL PRESSURE (DP)
0-5 PSI	DP=1.2581×(Reading Voltage)-1.2823
0-0.5 PSI	DP=0.1221×(Reading Voltage)-0.102

Thus,

$$\boldsymbol{Flow\ rate\ (Q) = 3.2497\ KgS^{-1} \quad Pressure\ drop = 0.8983\ psi}$$

The mean velocity of the flow in pipes can be calculated from flow rate by,

$$\boldsymbol{V = \frac{Q}{\rho(\pi r^2)}}$$

Where, Q is flow rate, r is the radius of 1inch pipe (0.01101m) and ρis the density of the fluid (997.1kg/m^3).

$$\boldsymbol{V = 8.56 m/s}$$

The generalized Reynolds number for non-Newtonian power-law fluid is defined as,

$$\boldsymbol{Re_g = \frac{D^n V^{2-n} \rho}{\frac{k}{8}\left(\frac{6n+2}{n}\right)^n}}$$

Where n, k are power law constant which can be obtained from bench-scale experiments result, for this combination, n=0.4373 k=0.2014. D is the diameter of the pipeline (0.02202 m).

So at this time, $\boldsymbol{Re_g = 76238.67}$

Also, shear stress of this fluid is termed as,

$$\boldsymbol{\tau_w = \frac{\Delta p\ D}{4L}}$$

In this formula, L is the length between two testing points (L=0.9104m in 1inch pipe),

Thus, $\boldsymbol{\tau_w = 33.24}$

After getting mean velocity, shear stress and density, the friction factor can be figured out easily,

$$\boldsymbol{f = \frac{\tau_w}{\frac{1}{2}\rho V^2} = 0.000909}$$

Comparing with Dodge-Metzner Equation, the same generalized Reynolds number is applied to the following equation,

$$\frac{1}{\sqrt{f}} = \frac{4.0}{n^{0.75}} log_{10}\left(Re_G f^{1-\frac{n}{2}}\right) - \frac{0.4}{n^{1.2}}$$

Empirical friction factor by non-Newtonian fluid in a smooth pipe is calculated by using R language, getting $\boldsymbol{f_0 = 0.002451,}$

So, $\boldsymbol{\%DR = \frac{f_0 - f}{f_0} \times 100\% = 62.9\%}$

Comparing with Blasius Equation, the friction factor of a Newtonian fluid (water) is figured out at the same mass flow rate as that of PAM-PEO solutions. Reynolds number is analyzed in terms of conventional Reynolds number equation,

$$\boldsymbol{Re = \frac{D\rho V}{\mu}}$$

Where μ is the viscosity of fluid, because the fluid is water, μ =0.00089 PaS. So the Reynolds number of water flow at the same mass flow rate is equation to,

$$\boldsymbol{Re\ (water\ flow) = 211233.6}$$

Applying this Reynolds number to Blasius Equation,

$$\boldsymbol{f_1 = \frac{0.079}{Re^{0.25}} = 0.003685}$$

Thus, the percentage of drag reduction comparing with Blasius Equation is,

$$\%\boldsymbol{DR} = \frac{\boldsymbol{f_1 - f}}{\boldsymbol{f_1}} \times \mathbf{100}\% = \mathbf{75.32}\%$$

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