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New Mixer Optimizes Crude Desalting Plant

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Abstract

Saudi Aramco Gas Oil Separation Plants (GOSPs) utilize conventional static mixers (usually globe valves) for mixing of crude with fresh water (wash water) as part of the desalting process. This mixing method often results in consuming high quantities of wash water and chemicals with relatively low mixing efficiency.

In order to optimize GOSPs' operations, a trial test of a new mixing technology provided by ProPure was conducted at Shedgum GOSP-4 during the period December 2007 – May 2008. The ProPure mixing system technology (ProSalt mixer system) was installed at the inlet line of the desalter in parallel to the arrangement of the conventional mixing valves (three in parallel).

The objective of the test was to evaluate the technology performance and reliability in optimizing desalting processes for Saudi Aramco crude processing facilities. This can be achieved by providing more efficient and effective use of wash water and chemicals while maintaining GOSPs treated crude specifications within Saudi Aramco acceptable criteria which are salt content below 10 PTB (Pounds per 1000 Barrels of Crude) and BS&W (Basic Sediment & Water) below 0.5% by volume.

At the end of the trial test, the Saudi Aramco team evaluated the ProPure mixing technology in comparison to the conventional type and concluded the following results;

- Pressure drop across the ProPure mixing system decreased by 60%
- Wash water rate was reduced by 40% (from 50 GPM to 30 GPM)
- Oil in water content reduced by 40%
- The salt content and BS&W have been on spec all the time

The paper describes the mixer concept and results at Shedgum GOSP-4 and further quantifies the implications on installation, treatment capacity and consumables as wash water and demulsifier.

1. Introduction

Produced crude oil is a mixture of hydrocarbon liquids, water and natural gas. The presence of water in produced oil characterizes crude oil as wet crude. This water needs to be removed from the crude oil before further processing. Water-in-oil is classified as two types; free water and emulsified water. Free water freely sinks to the bottom of any separator vessel found in the GOSPs since water has a higher density than oil.

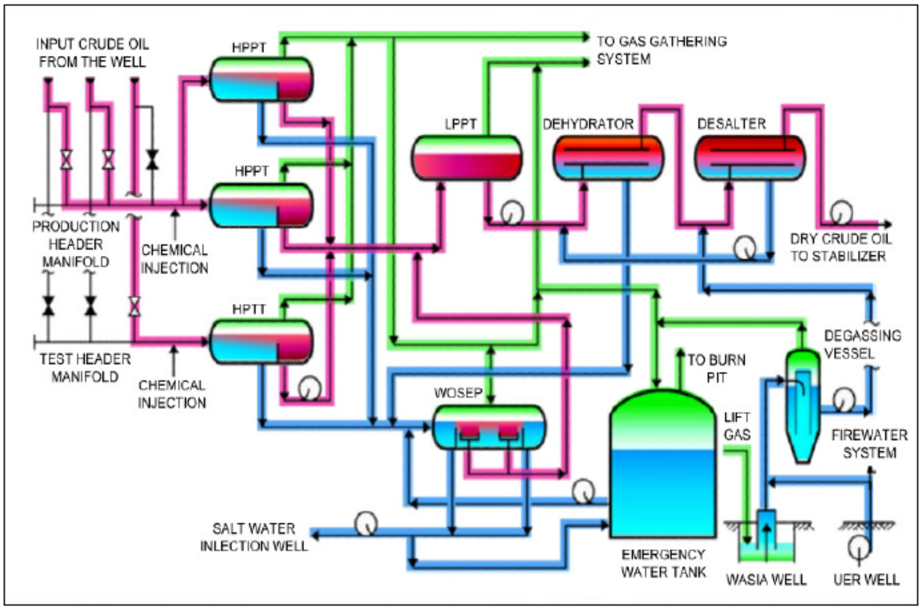


Figure 1: Typical GOSP Process

Emulsified water is traces of water still dispersed as liquid droplets through the oil phase. These water droplets tend to collide with each other forming a larger water drops that easily separate by gravity. By creating an oily film around each droplet, emulsions prevent those droplets from colliding with each other. To counteract the effect of these emulsions, a chemical, referred to as demulsifier is injected in the oil stream to break these films which will promote free water removal from the crude in the Dehydrator/Desalter vessel.

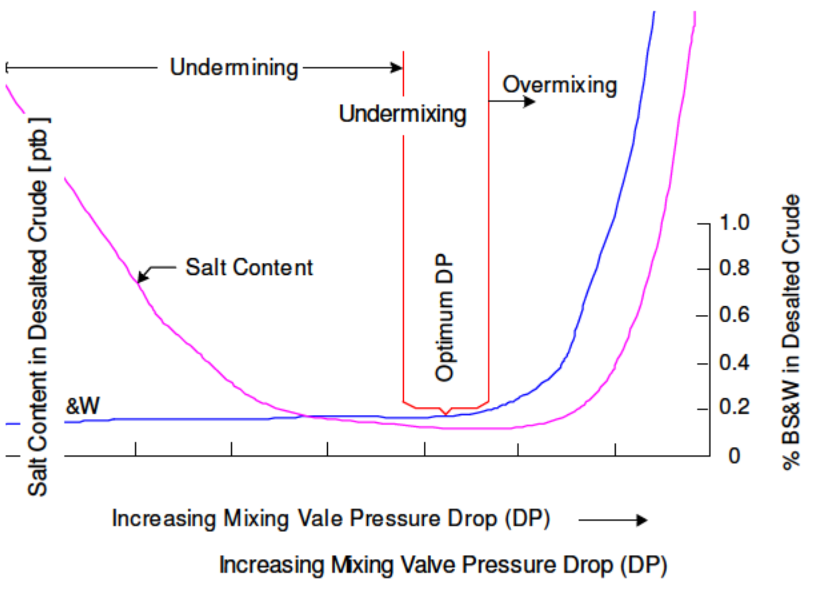


Figure 2: Optimum Mixing Valve Pressure Drop (DP)

The produced crude also contains some suspended and dissolved particles such as salts. The salts are dissolved in water, called brine water, except for a small amount of oil-coated salts. These salts are sourced to potentially cause corrosion, fouling, plugging, scaling, and other detrimental effects on processing facilities and downstream plants operations. The treated crude leaving Saudi Aramco GOSPs must be within Saudi Aramco acceptable specifications. Thus, the desalting process is a key preparation step for crude oil separation and refining processes.

The desalting process works by washing the crude with water (from WASIA well), then removing the water to leave dry, low salt crude oil. Figure 1 shows a typical GOSP process.

Efficient fluid mixing (wash water & crude) and exposure between the fluid phases are essential factors for unit operations. A conventional desalting process comprises injection of wash water (3-10 % of crude oil flow rate) utilizing static mixers or mixing valves for washing the crude oil with water. The conventional static mixers / mixing valves yield a high pressure drop (10 ~ 25 psig) which combined with non-homogeneous shear forces serve to generate undesirable stabile emulsions of water and crude oil. Figure 2 shows the location of the optimum mixing valve pressure drop that must be maintained for a conventional mixing valve.

In the Desalter vessel, electrostatic coalescers, imposing an electrical field which enhances the water droplets coalescence, are used for separating the salty wash water from the crude oil and the remaining emulsified water.

2. Background and targets for the mixer unit

Fluid mixing operations are essential both in the oil & gas industry and in the chemical process industry in general. Proper fluid mixing or contacting is decisive for the product quality and the operational reliability for crude processing facilities and downstream process equipment. Various production chemicals may be injected into the production stream to achieve flow assurance. Optimal performance of these chemicals depends on efficient mixing.

The target for the wash water-crude mixing process is to distribute the injected wash water into uniformly sized and separable water droplets. Consequently, the wash water is fully utilized if a high coalescence rate is achieved between wash water droplets and the dispersed (salt) water droplets entrained with the crude, at the same time as the water-crude mixture will become separable in the downstream separator.

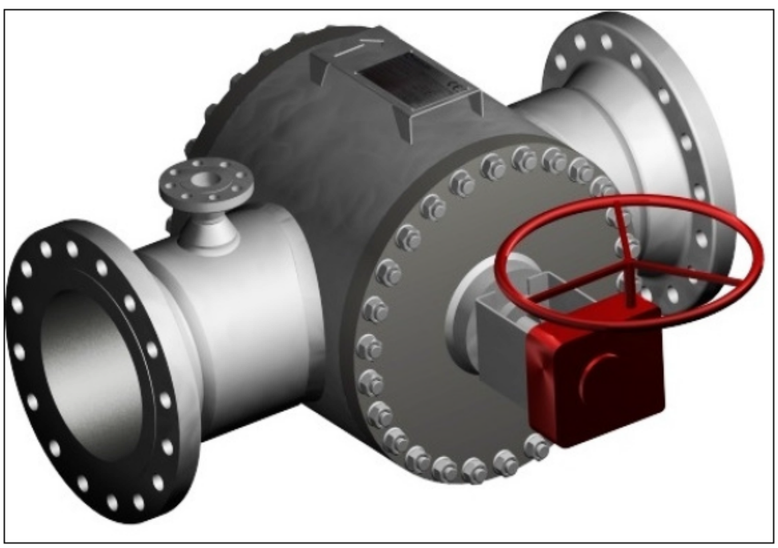


Figure 3: Typical ProPure ProSalt Mixer

ProPure AS, formerly named Framo Purification AS, established in 1999 by Statoil and Framo Engineering. The company is specialized in developing new and efficient technologies related to processes involving mass transfer operation. For this purpose ProPure has developed contactor solutions based on combinations of an injection mixer and an in-line mixer as shown in Figure 3.

Choke or globe valves which are widely used in Saudi Aramco processing facilities for the purpose of fluid mixing are old design. Those mixing valves results in non-homogeneous shear stress, in particular for the low cross-sectional area sections. This non-homogeneity and change in flow direction within the valve generates stabile emulsions of water and crude oil, thus affecting the liquid-liquid separability in downstream separators (electrostatic coalescers).

The ProPure mixing system (ProSalt mixer) ensures a homogeneous distribution and mix of wash water into the crude oil over the pipe cross-section. The gentle mixing and the controlled level of shear forces exposed to the mixture will generate less emulsions as well as improve the separation of the wash water and crude oil mixture. The ProPure mixing system design generates a narrow-sized distribution of separable water droplets over the pipe cross-section, accomplished at lower pressure drop than with the conventional methods, and with the potential to reduce the consumption of the wash water and chemicals and to operate at higher production rates. Mixing of liquids (water and crude) is illustrated in Fig. 4 for the two alternative configurations; conventional globe (top) and ProPure mixing system (bottom).

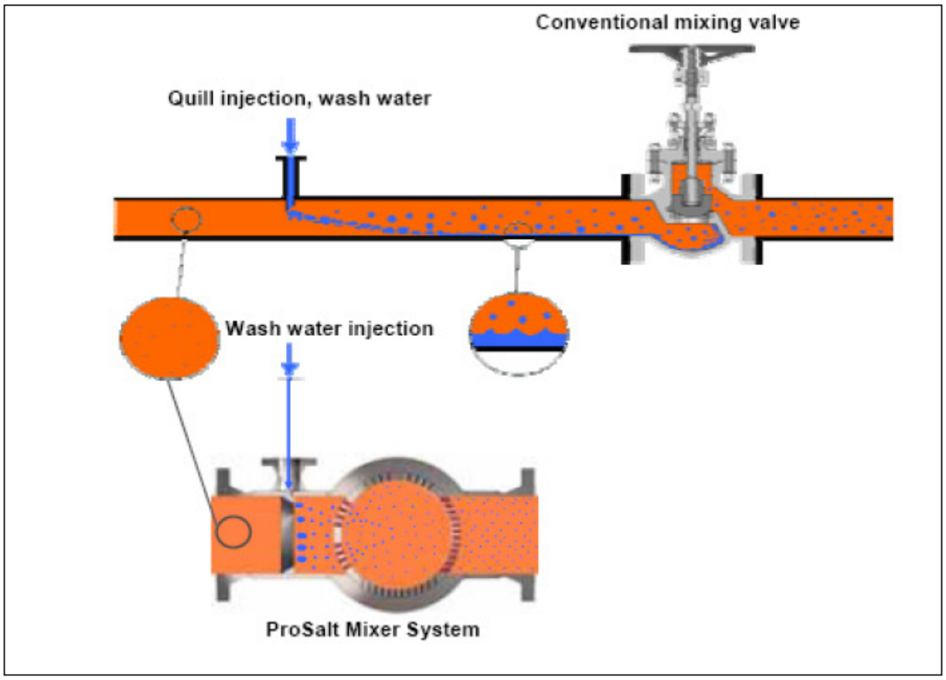


Figure 4: Wash water phase distribution with conventional globe valve mixer (top) & ProSalt mixer system (bottom).

2.1 Technology Description

The ProPure mixing system is designed to inject and mix wash water into the crude oil flow in order to remove the required amount of salt from the crude with a minimum consumption of wash water and with a minimum of pressure drop. The mixer system has the form of a single pipe spool as shown in Figure 5. The mixing intensity and pressure drop can be adjusted and controlled by an actuator or manually operated gear box. The injection mixer part of the system can handle any flow rate of wash water relevant to the application.

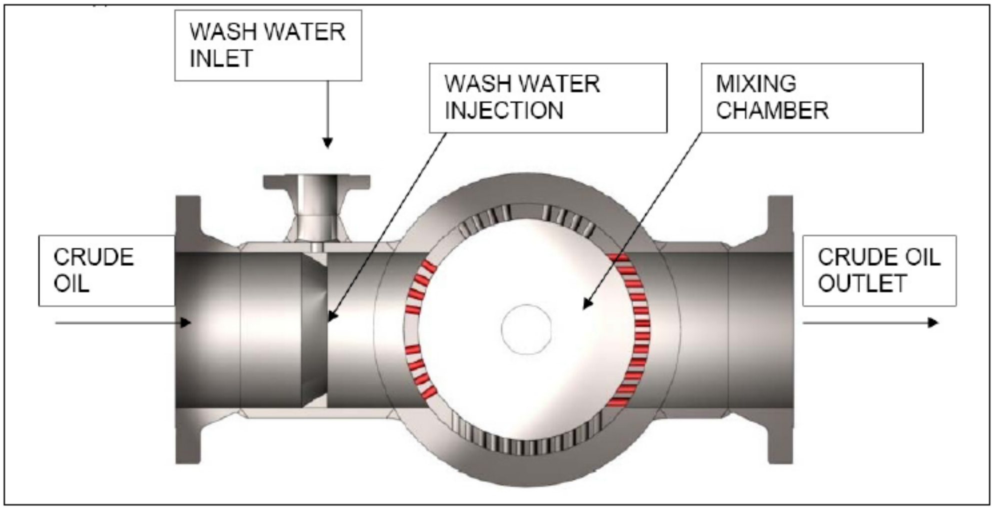


Figure 5. Typical ProSalt Mixer

The channels at the mixer inlet side are arranged such that the generated jet-flows are directed towards a common focus line. This is according to a “finger folding” pattern between the channels pointing upwards and downwards respectively. A certain shear stress is needed for the break-up of the dispersed phase. With the channel arrangement, high shear flow conditions in the whole mixing chamber are enabled and efficient mixing can be achieved with a low or moderate pressure drop. At the outlet side, the channels are designed to represent a certain pressure drop exceeding the frictional pressure drop for the pipe flow; the flux of the homogeneous multiphase flow mixture will be distributed evenly over the pipe cross section by the outlet channels. The pressure drop over the outlet also serves to reduce the short-circuiting of the flow within the mixer chamber.

As a result of the moderate variations in shear stress as exposed to the dispersed phase, the droplet size distribution becomes relatively narrow, which improves the performance of the downstream separator. This is different from the non-homogeneous shear stress exposure imposed with e.g. a globe valve, where the droplet size distribution reflects a considerable high phase fraction of small non-separable droplets, resulting in improper crude-water separation.

2.2 Principle of Operation

The ProPure ProSalt mixer system is a combination of the ProPure C100 injection mixer and the ProPure M100 in-line mixer, see Fig. 4, bottom, and Fig. 5. The wash water is supplied to the contactor through an annulus where the wash water is transformed into liquid droplets. This is done by locally increasing the dynamic pressure of the flow. The large area distribution of the injected wash water as imposed by the C100 Injection Mixer, serves to distribute and expose the wash water well within the crude oil as compared to a single quill or nozzles. The dispersed wash water-crude flow pattern set up by the injection mixer makes a convenient and homogeneous crude-wash water flow feeding the channels of the mixing cylinder. Thus the fluxes to the individual jet flows are considered homogeneous both in terms of wash water fraction and wash water droplet break-up.

The turbulent eddies as set up by the specific geometry, enhances mixing further for the downstream pipe flow. As a result, a high degree of mixing with a correspondingly large interfacial surface can be achieved at a low to moderate pressure drop with the C100 mixer. By rotating the position of the mixing cylinder (from 0º to 60º, typically) by the use of e.g. an actuator or gear box, more or less jet flow channels can be made accessible. Acordingly the shear stress exposure, controlling the resulting mean droplet size, can be varied, allowing for optimal pressure drop operation of the mixer unit. Equivalently, this operation also alleviates for turn-down capability of the mixer unit.

By this principle of operation the mixing system optimizes for narrow droplet size distribution, separable droplets, and homogeneous pipe cross-sectional droplet distribution at turbulent flow conditions. The flow conditions and droplet distribution of the wash water in the crude result in high coalescence rate between wash water droplets and dispersed water droplet entrained with the crude. At the same time the injected volume of wash water is well utilized for the purpose of wash water droplets to coalesce with the dispersed salt water droplets

3. Trial Testing

The objective of the trial test was to evaluate the effectiveness and reliability of the ProPure ProSalt mixer system in optimizing desalting process for Saudi Aramco processing facilities by improving mixing of crude with wash water with less pressure drop and high-efficient use of wash water.

The ProPure mixing system was installed upstream of the desalting system in the crude processing facility (GOSP) of Shedgum 4 to optimize desalting process. The technology qualification program targeted the following potentials:

- Lower salt concentration in crude
- More efficient use of wash water
- More effective use of chemicals
- Improved crude-water separation

The trial test was performed under the Petroleum Engineering and Development Special Testing Program. The role of this program is to introduce, deploy and recommend promising surface production technologies that can potentially optimize Saudi Aramco producing facilities operations and field development. The ProPure mixing system was tested at Shedgum GOSP-4 to verify if the ProPure ProSalt mixer system could increase the mixing efficiency, and at the same time as reducing the pressure drop.

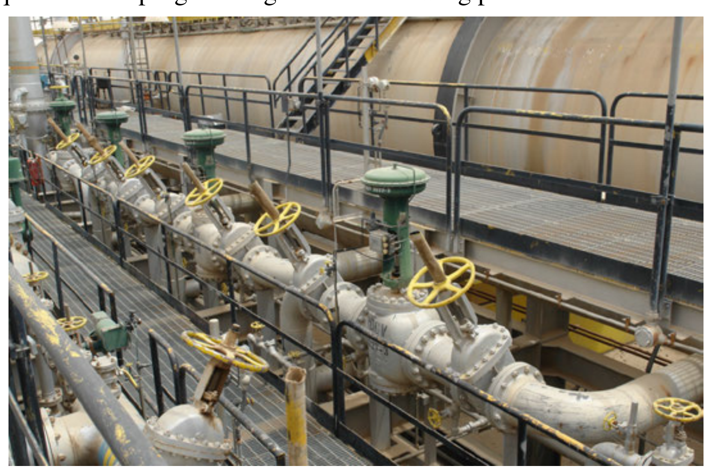


Figure 6: Parallel globe mixing valves prior ProSalt installation

3.1 Installation

An important constraint for the implementation of ProPure mixing system was to minimize modifications of the existing piping and mixing arrangement. The Installation of the ProPure ProSalt mixer system upstream of the Desalter, D-212 at Shedgum GOSP-4 including the wash water injection line required no modification of the existing piping systems except removing old pipe spools / mixing valve and replacing them with the new mixer unit and pipe spools. The installation of the ProPure ProSalt mixing system took approximately seven hours and was completed on December 17th, 2007.

Figure 7: ProPure ProSalt Mixer replacing globe valve section.

The crude oil line size from the Dehydrator to the Desalter is 24”, and there is a 24” header with 4 X 12” branch connections connected to three parallel mixing valves (PdCV3027 -1/-2/-3) and one manual operated valve (HCV3090). Figures 6, 7 and 8 show the installation of the new mixing system. The flow is collected in a 24” header before entering the Desalter. During normal operation the three mixing valves are in operation and the manual valve is closed.

The ProPure ProSalt mixing system is a 16” mixer unit with 12”, class #150 pressure rating flanges to fit into the existing piping system. The system replaced the existing mixing valve (PdCV 3027-1) and the upstream and downstream piping spools; corresponding length of the new mixer system is 1.85 m, (6.05 ft).

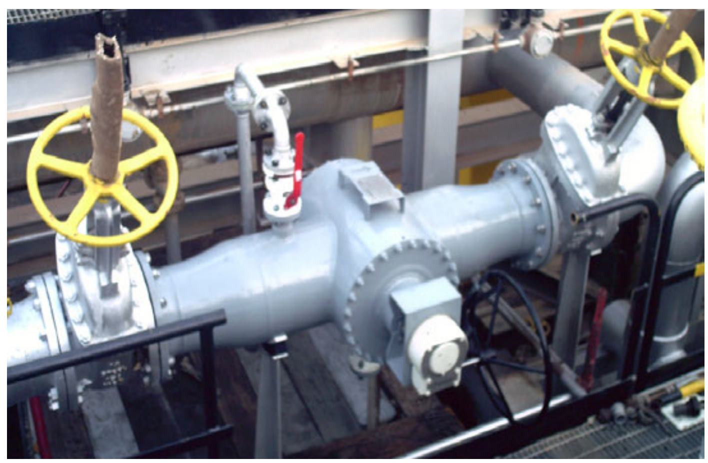


Figure 8: ProPure Mixing System in place

The ProPure mixer system was installed in parallel to the two remaining 12” mixing valves (PdCV 3027-2 and -3). When in operation the ProPure mixer system served to replace the existing mixing valves, and the easy switch between the parallel mixing alternatives enabled performance testing for the same process conditions. This is important in order to evaluate the performance of the ProPure ProSalt mixer system versus the existing mixing valves.

A 4” wash water injection line branch to bring wash water to the ProSalt mixer system was included in the existing 6” wash water system. This was done by replacing an old pipe spool with new pipe spools and valves. As for the testing the wash water injection should alternatingly be inject to the existing mixing valves and to the new mixer unit. Therefore one extra 6” and one 4” shut-off valve were included.

The installation was performed as per Saudi Aramco safety procedures and guidelines. The installation of the new mixer system was implemented while the Desalter trap was shut down and the affected line was depressurized, drained, and completely isolated. All fabricated wash water spools were fabricated at Saudi Aramco fabrication shop.

3.2 Field Testing

The trial test begun on December 17th, 2007 and was completed on May 31st, 2008. The intention was to handle the pilot testing with a minimum of disturbing effects and impact towards the ongoing operations at Shedgum GOSP-4.

The basic for the new mixer system performance characterisation was the comparison with the existing mixer valves arrangement which accordingly served as a reference. Thus for each process condition the performance was measured for both alternatives. The performance was based on the properties reflecting the fluid quality as achieved with the combination of operational mode, mixer concept and separator. Accordingly the quality was address by the concentration measurements of water-in-oil, oil-in-water and salt in crude. Three set of samples were collected regularly during the trial as follow:

- Crude oil in to the desalter D-212
- Crude oil out from desalter D-212
- Effluent water out from desalter D-212

Data were recorded every two hours, where salt content and BS&W of the Desalter oil out were closely monitored. Reducing the need for the wash water pump G-203A/B discharge was one of the parameters to be monitored in order to verify energy saving and associated maintenance costs through reducing loads on the charge pumps and D-211/D-212 transformers. Also, during these tests, the optimization of wash water was observed. It is also worth mentioning that some data were collected prior to the installation of the ProPure mixing system to serve as a base line when performing data analysis and to ease the comparison between both the new system and the conventional one.

Operational considerations:
Only two of the existing three mixing valves were available for operation. At high crude oil flow rates, the manually operated globe valve could be operated in addition to either ProPure mixing system or the two existing mixing valves. It was possible to switch between the existing mixing valve and the new mixer system to repeat all tests with both mixers alternatives at the same process conditions.

Demulsifier was injected upstream the HPPTs (D-201 & D-1) separator. No demulsifier was injected upstream of the Dehydrator, only an emergency system is available for injection upstream of the Dehydrator, and thus it would not be easy to quantify demulsifier optimization with the new mixer configuration.

The Wash water injection flow rate was calculated and controlled as a percentage of the crude oil flow rate. With the new mixer system in operation, the whole crude oil production flow rate had to pass the 12" existing pipe sections upstream and downstream of the new mixer system. This represented an additional pressure drop to the pressure drop across the mixer unit itself.

The position of the mixer internal (cylinder) can be adjusted to either keep the pressure drop constant when the flow rate is changing, or to increase or decrease the mixing intensity of the wash water and the crude oil to optimize the process performance. The injection mixer part of the system could handle any flow rate of wash water relevant to Shedgum GOSP-4 application.

The new mixer system was in operation once wash water was fed into the wash water injection port of the mixer unit at the same time as crude oil was flowing through the system.

Shedgum GOSP-4 Process Conditions:
The ProPure mixing system was designed based on the following process conditions:

- Operation Pressure Dehydrator (D-211): 130 psig, (9 barg)
- Operation Pressure of Desalter (D-212): 110 psi (7.6 barg)
- Design Pressure (Dehydrator/ Desalter) = 205 psig (14.1 barg)
- Design Temperature (Dehydrator/ Desalter) = 155°F (68°C).
- Oil Production Rate: 100,000 – 290,000 BPD
- Oil deg Gravity API: 35.9 (normal)
- Wash Water Rate to Desalter: 50 US gal/min, (11.4 m^3/h)

3.3 Test Results
The ProPure mixer system was operated for several process conditions settings, each test lasted for at bleast 4 days, including wash water flow rate, demulsifier rate and distribution and oil in effluent water. For some of the test conditions the mixer internal (cylinder) was adjusted to see the impact of the pressure drop, covering the pressure drop range 2 – 6 psi (0.14 - 0.41 bar) over the ProPure mixer. For all the tests the salt concentration was well below the spec. of 10 ptb, and typically in the range 5 – 7 ptb.

The robustness on crude desalting performance was readily seen, and apparently no impact on crude desalting performance was recorded by reducing the wash water rate from 50 to 30 US gal/min. Relevant time series for the two operational wash water modes are shown in Appendix A. The upper time series collection represent the higher wash water rate, the lower time series collection the lower. Time series are included for desalter temperature, demulsifier rate1st and 2nd injection, wash water rate, crude oil rate (notice unit kBPD), pressure drop and salt content in treated crude.

Tabulated averaged results are listed in Table 1 for the same parameters as shown as time series in Appendix A. By comparison with the similar results with the globe valve in operation, the following findings apply with the shift from globe valve operation to ProPure mixer operation:

- Pressure drop across the ProPure mixing system has been optimized and further decreased by 60% in comparison to the conventional mixing system
- Wash water rate has been decreased by 40% (from 50 GPM to 30 GPM).
- Crude oil loss to effluent water has been decreased by 40%.
- Salt content has been on spec all the time. The test results illustrate the great advantage of ProPure mixer system and its reliability and performance

which is one of the major prospective advantages of this technology.

Table 1: Test Results Summary

TEST NO.	TEST MODE	DESALTER TEMP. [DEG. F]	WASH WATER RATE [GPM]	TIE-LINE OIL RATE [BPD]	1ST DEMULSIFIER INJ. RATE [GPD]	2ND DEMULSIFIER INJ. RATE [GPD]	PROPURE MIXER DIFFERENTIAL PRESSURE [PSIG]	SALT CONTENT DESLATER OUT [PTB]
1	ProSalt Mixer @ 0 degree w/ 50 gpm of Wash Water	117.00	49.37	205.30	93.44	64.05	3.35	5.66
2	ProSalt Mixer @ 20 degree w/ 50 gpm of Wash Water	121.09	48.91	216.22	49.19	67.24	6.07	5.93
3	ProSalt Mixer @ 10 degree w/ 50 gpm of Wash Water	120.49	49.52	205.60	57.71	108.30	3.58	6.85
4	ProSalt Mixer @ 0 degree w/ 50 gpm of Wash Water	118.98	51.56	195.39	63.23	93.49	2.80	6.63
5	ProSalt Mixer @ 0 degree w/ 40 gpm of Wash Water	134.99	44.78	172.15	77.65	39.29	1.94	6.67
6	ProSalt Mixer @ 0 degree w/ 30 gpm of Wash Water	139.90	33.30	167.98	28.17	26.22	2.13	5.67

4. Discussion

The results support the qualitative description of the mixer characteristics related to shear stress exposure and resulting droplet size distribution, and further its impact on the crude desalting process. Clearly, the favourable desalter performance is associated with homogeneous and moderate shear stress exposure as generated by the ProPure mixing system.

During the test campaign the demulsifier injection rate was only moderately varied as its impact on the desalter performance was limited only. This is due to location of the injection point, as the demulsifier is injected upstream of the High Pressure Production Trap (HPPT). Accordingly this set-up makes it difficult to quantify and analyze how the demulsifier is affected by the new mixing system.

Due to the location of the demulsifier injection points in Shedgum GOSP-4 being upstream of the HHPTs, the demulsifier consumption optimization can only be recognized at the early stage process separation. It is not an easy task to quantify for demulsifier consumption optimization when it comes to the Electrostatic coalescers stage (Desalter and Dehydrator). However, for downstream plants, this task can be easily determined since the demulsifier injection points are upstream of the desalting process. For this reason, future investigation for downstream applications of the mixer system is recommended.

For the desalter process facility in concern, the energy loss due to the lower pressure drop over the mixer is considered as less important compared to the reduced wash water consumption and the higher quality of effluent water and treated crude.

5. Conclusions

Based on the trial test results the following were observed and concluded by changing from globe valve mixing to homogeneous shear stress mixing as established by the ProPure mixer system:

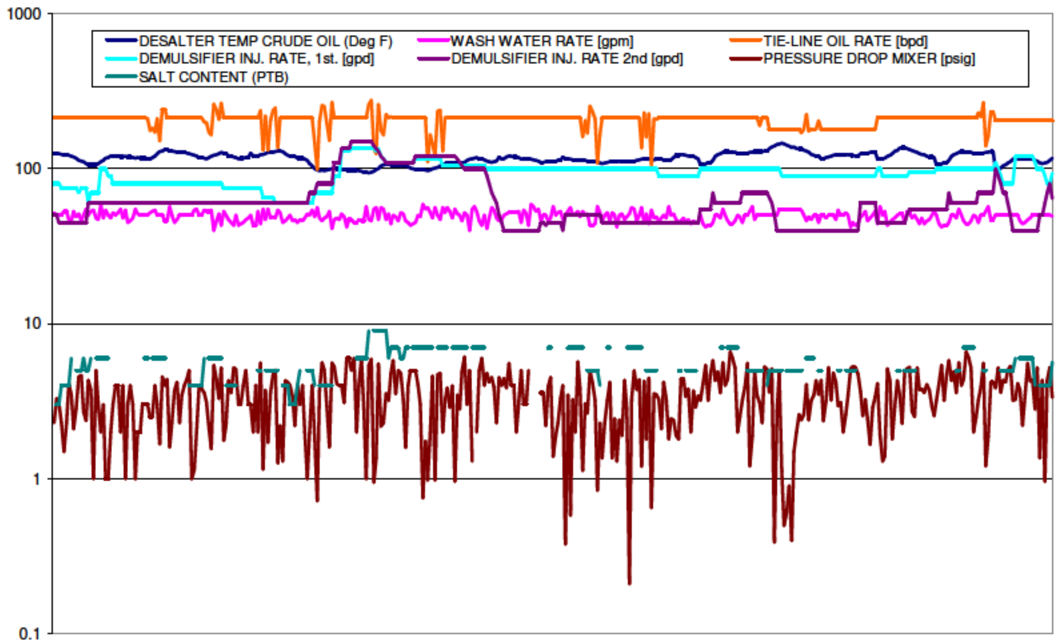
- Increased mixing efficiency at reduced pressure drop
- Wash water consumption has been lowered significantly
- The homogeneous shear stress mixing system can be utilized to simplify process design of GOSPs and downstream plants where applicable.
- ProPure mixing system supports process optimization and enhances the quality of Saudi Aramco shipped crude.
- The tests have demonstrated that the mixer system applied is a key process component in the Desalter process, with considerable impact on desalting capacity and performance.
- Due to its compactness and wash water droplet generation the ProPure mixing system technology can potentially replace the conventional mixing configuration for desalting process with high desalting efficiency.

APPENDIX A. SELECTED TIME SERIES – PROPURE MIXER IN OPERATION

In order to demonstrate performance characteristics two different operational modes, time series for the following has been selected, ref. Table 1:

- Test no.1: Wash water rate 49 USgal/min / crude oil rate 205 kBPD
- Test no.6: Wash water rate 33 USgal/min / crude oil rate 168 kBPD

Test No. 1
ProPure Mixer Fully Open @ 0 Degree Position



Test No. 6
ProPure Mixer Fully Open @ 0 Degree Position with 30 GPM of Wash Water

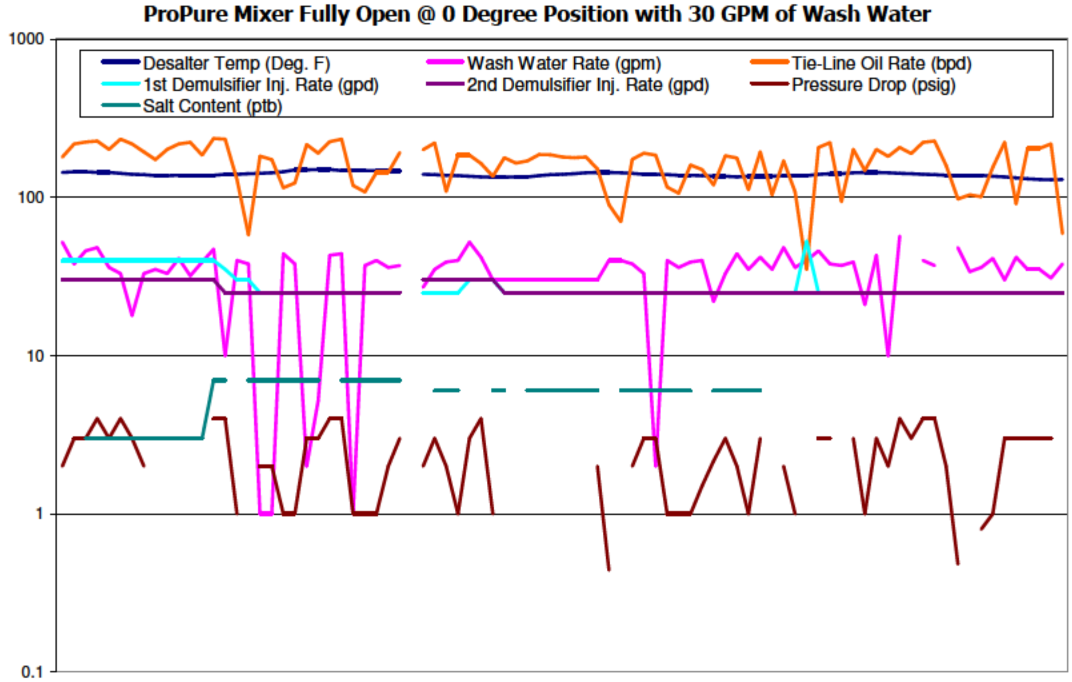


Figure A-1 : Process data time series ProPure mixer in operation, tests 1 (top) and 6 (bottom).