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# Field Trials Scheduled for New Compact Dehydration Technology

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## Abstract

Significant improvements in the capacity and performance of existing oil dehydrators and desalters are expected from an improved, patent pending, transformer and controller system. This electrostatic system is now ready for a field trial in South America. Production at the selected facility is currently at 45,000 bopd per unit on a medium gravity crude oil. This oil is currently being processed by five 10-ft. diameter x 45 ft. long electrostatic dehydrators using combined AC/DC electrostatic technology. Pilot studies utilizing the improved transformer / controller have demonstrated capacity improvements exceeding 30% above existing technology or outlet BS&W reductions between 10 to 30%.

To confirm these results and define the limits of this new technology, a series of scheduled field trials has been planned. In addition, several other vessel modifications will include upgrading the inlet spreader design, and installing new high voltage electrodes.

Once these improvements are made and the new compact electrostatic technology is implemented, it is estimated the vessel capacity will increase significantly, while maintaining the required oil specification. If successful, this electrostatic transformer and controller may provide producers and refiners with a new technology to process highly conductive, viscous oils.

## Testing Objective

Utilizing a South American oil facility, a new electrostatic dehydration technology is scheduled to be field tested. The objective of these tests is to quantify improvements to the oil dehydration process, demonstrate the robustness of the equipment and establish confirmation of the laboratory test results.

## Facility

The production facility shown in Figure 1 has five oil dehydration vessels operating in parallel. Each horizontal dehydrator is 10 ft OD x 45 feet long x 125 psig with Dual Polarity® electrostatic technology, open bottom spreaders, either steel or composite high voltage electrodes and pipe collectors. The Dual Polarity transformers are 480 volt, single phase rated for 150 kVA. Following an upgrade of three vessels to improve performance, a fourth vessel is scheduled to be retrofitted with a new electrostatic transformer including step/start switchgear and PC-based process controller. The facility has the capability to increase the oil flow to the test vessel so the limits of the technology can be investigated.

Figure 1 – Field Site

## Application

The facility is currently processing a 27.1 API oil at flow rates varying between 45,000 bopd to 60,000 bopd per vessel. The operating temperature is maintained at 140 F and the operating pressure is 80 psig. At operating temperature the dry oil viscosity is 8.9 cp. The inlet water cut typically ranges between 20 to 30%. The outlet specification is less than 1% BS&W and is routinely met by the dehydration process.

These vessels use Dual Polarity electrostatic technology, as shown in Figure 2, to treat the inlet oil/water mixture.[1] Design features include inlet spreaders to distribute the incoming fluid evenly along the length and across the width of the vessel. The spreaders are open-bottom box-type, which permits bulk separation of free water and solids.

Oil/water interface is established just below the spreader holes so the inlet fluids are distributed into the oil phase. Approximately 24 inches above the interface is an array of electrodes. These steel electrodes are arranged in parallel at a spacing of 6 inches. The steel electrodes are 6 inches high and at their ends approach within 6 inches of the vessel wall. Alternating electrodes are energized with a positive voltage and adjacent electrodes are energized with a negative voltage. The positive and negative voltages are supplied from a 100% reactance, 23 kV (rms) transformer.

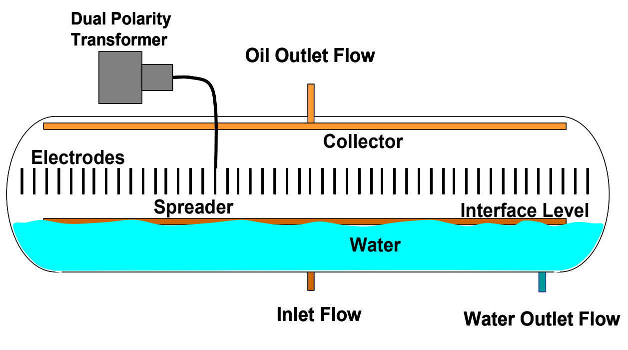


Figure 2 – Dual Polarity Vessel Configuration

A single collector is located at the top of the vessel containing a series of holes located on opposite sides. The collector is optimized to ensure uniform collection along the length of the vessel. A single outlet nozzle is located near the center of the vessel.

Following installation of the new electrostatic transformer, it is expected the oil flow can be significantly increased by as much as 30% without an increase in the effluent BS&W levels. Alternatively, the new technology is expected to lower the effluent BS&W 10 to 30%.

## Technology

The electrostatic technology to be applied utilizes a proprietary process controller and transformer package to produce an electrostatic field that can easily be optimized for any crude oil. This technology has been in development for over 4 years and has demonstrated remarkable performance improvements in pilot facilities.

The transformer consists of three primary components that are packaged in a single oil-filled enclosure. Designed to operate on three phase, 480 volts (50 / 60 Hz) the technology overcomes the load balance problem normally encountered with single phase electrostatic processes. First, the 480 volts is conditioned using IGBT technology (isolated gate bipolar transistors) to produce a variable amplitude and variable frequency voltage supply for the primary of the transformer. Second, the medium frequency transformer steps up the input voltage to a secondary voltage level necessary to promote effective coalescence. Third, the secondary voltage is rectified into positive and negative half-wave outputs. These polarized, half-wave voltages are then applied to the electrodes in a Dual Polarity dehydrator.

A PC-based process controller defines the voltage control environment to match the specific needs of the production. For example, where highly conductive crude oils are processed (> 80 nS/m), the frequency can be increased to maximize the energy delivered to the oil dehydration process. Utilizing a medium frequency transformer overcomes the voltage decay associated with conventional 50/60 Hz transformers. In wet crude oils the effective impedance may be very low, resulting in a rapid, voltage decay from the process electrodes. This decay reduces the effectiveness of the dehydration process by pulling the voltage below the threshold level required for effective dehydration. Operating with an increased frequency reduces this voltage decay and effectively sustains the applied voltage above the required threshold.

Also, where the interfacial tension between the oil and water is low (< 10 dynes/cm) the waveform can be reduced to minimize destruction of the water droplets normally caused by the application of 50/60 Hz power. Chemicals, temperature, salts and applied voltages combine to reduce the interfacial tension between the dispersed water droplets and the crude oil. This low interfacial tension reduces the natural frequency of the entrained water droplets. Reducing the frequency of the waveform can prevent the destruction of the large water droplet required for effective dehydration.

Furthermore, the shape of the voltage waveform can be selected to achieve the best dehydration results. Finally, the minimum and maximum voltage levels can be set to increase the percentage of the entrained water that is swept by the electrostatic voltage. Maximum voltages reach the smallest water droplets with sufficient energy to develop a surface charge and promote coalescence.[2] Reducing the voltage to a minimum level will maximize the droplet growth to promote a rapid sedimentation rate.

The PC-based controller developed to control the output of the variable voltage / frequency transformer is capable of producing a nearly infinite variety of waveform configurations. Selectable variables include the frequency of the voltage, the maximum and minimum voltages applied to the transformer and the cyclic pattern and rate used to drive the transformer. Figure 3 depicts a typical envelope of the primary voltage using an exponential waveform. The waveform is skewed slightly to ramp up to the maximum voltage slightly faster than it ramps down to the minimum voltage. Sweeping the applied voltage across the threshold voltage optimizes the coalescence and separation of water from the incoming oil/water mixture.

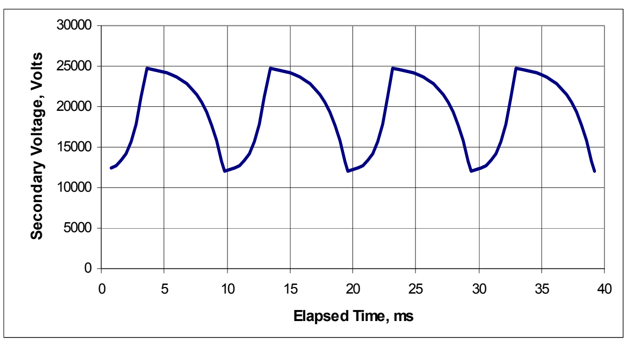


Figure 3 – Typical Exponential Voltage Waveform

Figure 4 schematically shows the component arrangement for the PC-based controller, the power electronics, the medium frequency transformer, the rectifiers (diodes) and the process vessel. The power electronics, transformer and rectifiers have been packaged in an oil-filled container to overcome distance problems between the electronics and the transformer, to provide cooling by the recirculation of dielectric oil and to make the retrofitting of existing AC/DC transformers more convenient.

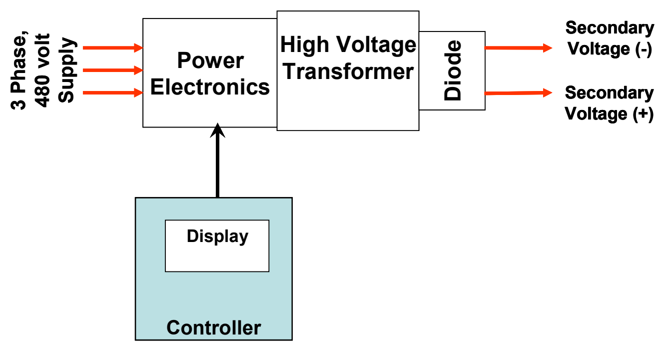


Figure 4 – Electrostatic Transformer / Controller Schematic

Unlike conventional 100% reactance electrostatic transformer designs that develop a significant drop in output voltage as the load increases, this new transformer is capable of maintaining maximum output voltage, even at the maximum rated current. To provide sufficient voltage to sustain the dehydration process under a wide range of process conditions, conventional transformers cannot be operated beyond 40% of their rated current.

## Preliminary Results

Extensive lab tests have provided ample evidence the variable voltage / frequency technology can be optimized to permit excellent oil dehydration at significantly higher oil flow rates in a given vessel size. To date pilot tests using this technology have achieved results similar to those shown in Figure 5 on a 24.85 API crude oil.

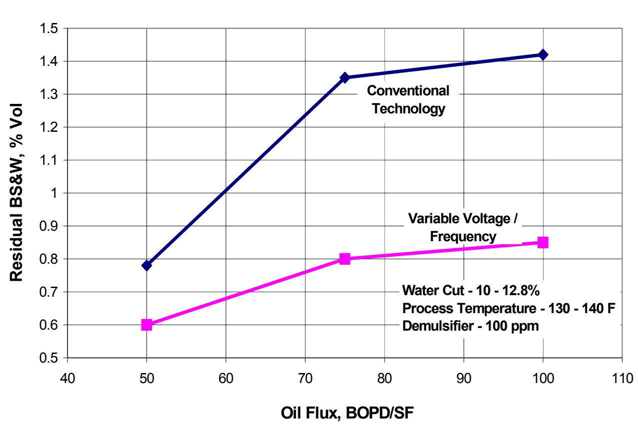


Figure 5 – Preliminary Pilot Results

These tests have demonstrated the strong dependence that voltage, frequency, and waveform have on efficient oil dehydration. Additionally, the development program has produced a voltage controller capable of producing a nearly infinite number of waveform configurations.

## Test Program

The testing will involve documentation of the current operating conditions, voltage configuration, chemical utilization and effluent BS&W. Data will be gathered periodically over a 21-28 day period to establish a strong baseline. While the variable voltage / frequency technology is capable of producing dry oil with low BS&W levels, the testing program will attempt to establish the most aggressive flow rate that achieve a 1% BS&W specification. After the baseline data has been collected, the new variable voltage / frequency transformer will be retrofitted to the process vessel. After installation the power supply parameters will be optimized using the effluent BS&W as the dependent variable. Once optimized, a second series of testing will be conducted to document the effluent BS&W at the same maximum process flow rate. If the outlet BS&W declines, then the production rate through the vessel will be increased again to determine the most aggressive flow rate that will achieve 1% BS&W. If possible, additional tests may be conducted to determine the minimum chemical dosage.

## Expectations

Installation of the variable voltage / frequency power supply will achieve the following results immediately:

**Balanced electrical load** – The new electrostatic power supply is designed to operate on a 480 volt three phase circuit. It immediately converts this AC voltage to a 750 volt DC bus. Therefore, regardless of the energy required by the dehydration or desalting process the load on each branch of the input power will remain balanced at all operating conditions.

**Increased power available during process upsets** – Conventional transformers are designed with 100% reactance. When process upsets occur that require more energy, these transformers can fail to maintain sufficient voltage to sustain coalescence. The variable voltage / frequency power supply is designed with a low reactance permitting the maximum available current to be delivered to the process without a reduction in secondary voltage.

**Ability to select waveform for optimum performance** – Operating the IGBT modulator at a high switching frequency permits the modulation waveform to be easily customized. Matching the waveform to the electrostatic needs of the process it is possible to promote maximum droplet coalescence.[3] Four variables can be used to define the shape of the waveform.

***Minimum Voltage*** – used to maximize the water droplet diameter.

***Maximum Voltage*** – used to energize the smallest water droplets.

***Frequency*** – prevents the voltage applied to the positive and negative electrodes from decaying, thus maximizing the electrostatic energy applied to the dispersed water and controls the droplet growth and maximizes the water droplet population.

***Waveform*** – may be any conceivable cyclic wave that can be represented mathematically. The controller has been configured with the following waveforms: logarithmic, exponential, sinusoidal, square, sawtooth, trapezoidal, circular and inverse circular. The exponential waveform is represented in Figure 2. Additionally, the controller permits these waveforms to be skewed to alter the ratio for ramp up and ramp down times.

Results have been obtained in laboratory tests using a range of crude oils. In some cases, the actual results were significantly better than those expected in the field trials. Based on laboratory data, the process performance after installation of the variable voltage / frequency power supply is expected to achieve the following results:

**Process up to 30% more oil** – Once the waveform has been optimized the performance of the process is expected to improve by at least 30% in oil capacity processed through the vessel. In many lab tests, the results have been superior to 30%. In the field vessels that maximum oil flow may be limited by the outlet nozzle diameter and not the electrostatic capacity of the vessel.

**Achieve up to 30% reduction in the effluent BS&W** – Alternatively, if the oil flow is held constant, the outlet BS&W is expected decrease by as much as 30%. In some pilot tests the effluent BS&W has been successfully reduced to trace levels.

**Improve effectiveness of demulsifying chemical** – Electrostatic processes function on the water droplet surface the same as the demulsifying chemicals. While actual chemical reductions may not be realized, it is likely the effectiveness of the demulsifying chemicals will be improved.

**Maintain performance at a reduced temperature** – The variable voltage / frequency power supply produces a significant increase in the water droplet diameter, these enlarged droplets will settle rapidly at the operating temperature. With these enlarged droplet diameters the oil viscosity may be permitted to increase by reducing the oil temperature.

## Conclusions

This patent pending, variable voltage / frequency power supply has been developed during the past 4 years by NATCO. With the ability to fashion a waveform that is optimized for any crude oil, this technology will expand the utility of electrostatic dehydration into opportunity crudes including SAGD production in Canada, diluted bitumen in South America, as well as high TAN crudes.

The functionality of the transformer permits an electrostatic field to be optimized for oil viscosity, flowrate, oil conductivity, interfacial tension, water droplet population and distribution.

This technology will permit a significant reduction in size from conventional electrostatic vessels. It can also be easily retrofitted for debottlenecking existing Dual Polarity treaters without vessel entry. This patent pending technology, trademarked as Dual Frequency ™, will extend the application of electrostatic dehydration to more difficult oils.

## References

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