Increased availability and lower costs have caused refining margins to nearly double, making opportunity crude (crude oils with API gravities of 20 or less) attractive to refiners. However, that attraction can fade for several reasons: opportunity crudes must be blended with lighter API crudes to reduce viscosity and adjust gravity to meet the ideal refining condition of 25 - 30 API. Furthermore, salt, water, inherent contaminants, oilfield additives and equipment limitations can make these crude blends difficult to process. As a result of the potential they have to foul and corrode downstream equipment, these undesirable components must be removed from the crude before it reaches any of the major unit operations. A key part of this refining process is desalting.

The desalting process begins by mixing low salinity wash water with the blended crude to ensure good contact efficiency and removal of the diluted brine droplets when using electrostatic desalters. It does this by providing efficient brine droplets coalescence, growth, and gravity settling inside the desalters. The crude oil desalting process can be conducted in a single, double, or triple stage, although two stage desalting is the most common. Crude oil salinity is often expressed as ptb (pounds of salt per 1000 bbls of crude oil).

Crude oil is heated in the crude oil heat exchanger to reduce the crude oil viscosity. The lower crude oil viscosity provides a faster settling of brine (saline water) droplets in the crude oil and also improves the mixing of...
wash water and brine droplets. Ideally, wash water should be heated to a temperature no less than 15°C lower than the crude oil temperature. The wash water should also be deoxygenated to avoid corrosion inside the desalter and should have a pH of approximately 7.

**Fluid properties**

In addition to crude with API gravities of 20 or less, there are sub definitions for very heavy oil (API 14 and below) and extra heavy oil (API 11 and below). Besides having a higher density of 934 kg/m³ at 20°C and higher, heavy crude oil has a number of other characteristics:

- High viscosity.
- Lower formation water salinity.
- Higher solids loadings.

The higher densities of heavier crude oils impact several operational factors, resulting in:

- A lower density difference between the crude oil and brine.
- A lower driving force for brine droplet separation.
- Higher operating temperatures, larger vessels, and higher demulsifier dosage rates are required.
- Higher capacity power units using lower voltage gradients to accommodate higher conductivity.
- Lower voltage gradients resulting in less efficient desalting.

For instance (as referenced in Table 1), the density differential at 120°C between an 18 API crude oil containing a 1% salinity brine is (950 kg/m³ - 879.6 kg/m³) = 70.4 kg/m³. By comparison, the density differential between a 30 API crude oil containing a 12% salinity brine is (1023 kg/m³ - 806.2 kg/m³) = 216.8 kg/m³.

**Table 1. Fluid properties**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>18° API Visc Density</th>
<th>1% Brine density</th>
<th>30° API Visc (cP) Density</th>
<th>12% Brine</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>214</td>
<td>931</td>
<td>999</td>
<td>11.5</td>
</tr>
<tr>
<td>80</td>
<td>31</td>
<td>905</td>
<td>979</td>
<td>3</td>
</tr>
<tr>
<td>120</td>
<td>9.5</td>
<td>880</td>
<td>950</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**Conventional desalters**

Conventional desalters use retention times, heat and alternating current (AC) electrostatic technology to treat crude blends. The electrostatic field in a desalter is affected by the electrical conductivity of crude oil. If the crude oil conductivity is very low, the electrostatic charge has difficulty reaching the dispersed water droplets. If conductivity is very high, some of the electrostatic charge may dissipate into the crude oil and never reach the water droplets.

The conductivity of the crude blend is directly proportional to the operating temperature of the desalter. The conductivity can also dramatically increase when opportunity crudes are blended in a refinery. The effect of increased crude oil conductivity in an AC desalter is a decreased electrostatic field. This leads to less effective dehydration, because the lower voltage cannot promote coalescence of small water droplets.

The coalescence of water droplets dispersed in crude oil occurs when the droplets collide with enough energy to overcome barriers to coalescence, such as films on the droplet's surface, dispersion of fine solids around the droplets, and high interfacial tension. Electrostatic fields generate forces that improve coalescence of water droplets resulting in improved water separation.

**Three electrostatic forces**

Dipolar force results in the water molecules aligning themselves in an electrostatic field. A water droplet made up of such aligned molecules is polarised with a positive charge on one end and a negative charge on the other end, causing them to be attracted to other water droplets.

Electrophoretic force moves water droplets in a uniform DC electrostatic field. With a force of up to four orders of magnitude larger than dipolar attraction, the water droplets collide more frequently.

Dielectrophoretic force, the weakest of the three electrostatic forces, moves in a non-uniform electrostatic field toward convergence of the electrostatic field.
AC crude dehydration technology
AC crude desalting technology applies an alternating electric field at 50 - 60 Hz to the emulsion, causing the water droplets to deform because of dipolar attraction force. The attraction force between oppositely charged ends of the water droplets speeds up the droplet coalescence. Desalters using AC fields are effective for bulk water removal, but their performance suffers when lower water cuts are processed. The lower water cut means the water droplets are farther apart, which weakens their dipolar attraction. DC fields use electrophoretic force to enhance water droplet collision rates and promote coalescence. Because the application of a DC field to an emulsion with significant water content results in electrocorrosion, the method is limited to desalters used in refined products.

Dual polarity technology
The NATCO® DUAL POLARITY® technology was developed in the early 1970s by The National Tank Company. In a DUAL POLARITY® desalter, the incoming wet crude oil emulsion is first subjected to a weaker AC field for bulk water removal followed by a stronger DC field where the remnant water droplets are removed. This design uses vertically oriented electrode plates transverse to the desalter length with alternate plates being charged positive and negative. Accordingly, this provides twice the voltage gradient to the water droplets and eliminates the possibility of a sustained DC current.

As the water droplets are carried by the crude oil into the electrode zone, they move toward the electrodes acquiring a charge and accelerating to the oppositely charged electrode. As droplets oscillate in the DC field, they collide and coalesce settling downward to the separated brine phase in the lower part of the desalter.

Dual frequency technology
The most recent of the enhanced electrostatic field technologies is the NATCO® DUAL FREQUENCY®, which was developed by the National Tank Company in 2004 and acquired by Cameron in 2009. This patented AC/DC solution for high conductivity crude oils is based on a problem: one set of electrode plates experiences charge decay while the alternate set of plates is being charged. The decay can result in the loss of the DC field. To minimise this effect, the frequency of power source is increased and that decreases the time between charges.

Replenishing the voltage on the electrodes at a faster rate strengthens the DC field in a desalter. DUAL FREQUENCY® desalters operate at a base frequency between 800 - 1600 Hz compared with 50 - 60 Hz for traditional desalters, which retain the DC field in high conductivity crudes.

The low interfacial tension of many crude oils can be used to promote droplet coalescence by modulating the voltage at a frequency close to the resonant frequency. The base frequency is set high enough to minimise field decay. Then, the modulation frequency is set to a rate that energises the surface of the water droplets; these frequencies are generated simultaneously.

DUAL FREQUENCY® desalters typically provide twice the flowrate of a conventional AC desalter, using the same size desalter vessel. They also improve mixing, reduce dosage of demulsifier and corrosion inhibitor chemical and improve handling of opportunity crudes.

Existing DUAL POLARITY® desalters can be upgraded with DUAL FREQUENCY® technology by replacing the power unit and adding the electronic control system. Operators using DUAL FREQUENCY® technology can tune the power unit to desalt opportunity crude blends. This gives refiners other options besides adjusting chemistries, temperatures, and flow rates, enabling them to optimise operations without incurring additional Opex.

Conclusion
From an operational viability standpoint, refiners who replace conventional AC desalters with AC/DC desalter technology to process opportunity crudes will realise several key advantages: improved desalting efficiency, increased crude flowrate, reduced operating temperatures and emulsion chemistries. AC/DC desalters also require less electric power, use less wash water, and produce cleaner effluent water.