Fractionated Water Recovery

January 20, 2010

North American shale gas plays discovered over the past ten years contain an abundant tcf of natural gas, providing a long term, low carbon domestic energy source. Drilling and completion techniques developed in the Texas Barnett Shale over the past ten years have unleashed an unprecedented new shale gas industry across North America. The most effective completion technique is known as hydraulic fracturing (or “fraccing”), a process that involves injecting a large volume (60,000 to 100,000 bbls) of fresh water underground to fracture the formation, increasing permeability and thus gas flow. After a frac is completed, a large portion of the frac fluid returns to the surface as “flowback” water which contains high concentrations of dissolved salts, frac chemicals, and formation minerals. The costs and logistics of managing both fresh and flowback water in shale gas plays are problematic. Development of North America’s shale gas resources will require well developed water management strategies that include the effective implementation of water recycling technologies.

Water and the key role it plays in the development of non-conventional oil and gas reserves such as shale gas is becoming a very contentious public issue, particularly in light of the recent development of the Marcellus Shale in the NE. This is emerging as a very severe environmental problem for operators and indeed for the entire gas shale industry. By making the recovery of and beneficial use of a portion of the brackish produced water from these shales efficient and cost-effective, an environmental liability can be turned into an asset.

Treatment and handling of flowback and produced waters associated with shale gas development is difficult due to high volumes, high contaminant loading, and high fouling potential. Conventional wastewater treatment equipment has not been able to effectively recycle these types of wastewaters with the exception of thermal evaporators. Flowback and produced waters have a high tendency for fouling and scaling in thermal evaporative systems. Components natural to these wastewaters such as polymers (polyacrylamides), hydrocarbons, carbonate based scales ($CaCO_3$), sulfate based scales ($CaSO_4$, $SrSO_4$, $BaSO_4$), silica based scales, and other suspended solids adhere to pipes, membranes, heat exchangers, and other critical components of recycling equipment that severely inhibit efficiency, water recovery, and on-line time. Components such as NORM have a tendency to accumulate in scales, making cleaning and disposal hazardous and expensive. The severity and variability of the high fouling potential of flowback water limit the widespread adoption of thermal evaporator recycling technologies.

The level of achievable water recovery is often the primary factor in the end-users adoption of recycling technology as it dictates overall water management economics. This generally eliminates the use of membrane based technologies (RO, EDR, etc) due to their limited recovery on high TDS flowback. Increasing energy efficiency of thermal evaporator systems reduces operating costs and carbon emissions. Increasing the utilization factor allows for better use of all associated resources, ensuring that the maximum volume of water is recycled for fixed capital and operating costs. This reduces costs on a per volume basis so that recycling operations are economically sustainable and able to grow to meet market demand.

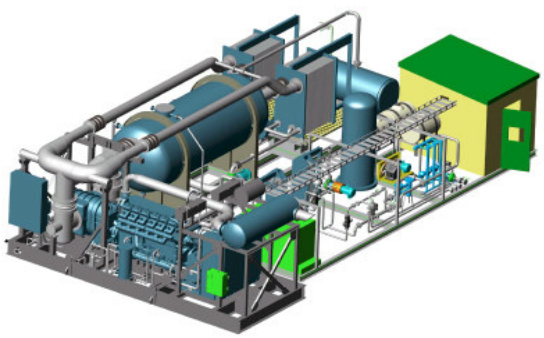
In 2003 Fountain Quail made contact with shale gas producers in the Texas Barnett field and began a search for solutions to managing shale gas water. Aqua-Pure Ventures from Calgary (Canada) worked with Fountain Quail to design the NOMAD 2000 - a mobile, modular version of Aqua-Pure's process patented Mechanical Vapor Recompression ("MVR") evaporation technology, specifically for operation in shale gas fields. The Aqua-Pure MVR technology was already in use for heavy oil applications at that time, and the NOMAD 2000 design built on Aqua-Pure's experience in handling oilfield produced water. Aqua-Pure eventually acquired Fountain Quail and established it as a service company based in Texas that owns and operates the equipment and charges producers for the water processed on a per volume basis. For the past six years, Fountain Quail has owned and operated its own equipment and used it in aggressive, high fouling water recycling applications. Fountain Quail monitored the performance and problems with the equipment designs and has made a series of design changes that have lead to step improvements in both system efficiency and reliability. A high level of in-house knowledge has been accumulated on corrosion, metallurgy, scaling and fouling, water chemistry, process optimization, and innovative construction techniques.

The NOMAD 2000 MVR Evaporator is a highly energy efficient process for producing distilled water from wastewaters contaminated with dissolved salts. Evaporative treatment involves the boiling of a solution such that contaminants remain in the liquid phase, while pure water vapor evaporates and can be condensed to distilled water. MVR evaporation differs from conventional evaporation in that a compressor is used to input the energy required to generate steam rather than a heat source such as a boiler. The high energy efficiency is achieved by utilizing the latent heat of the condensing steam as the primary energy source for boiling the wastewater. Conventional distillation requires 1000 BTU /lb of steam, while MVR evaporation requires a theoretical 25 BTU / lb of steam produced. The energy input by the compressor for MVR evaporation is required to compensate for the difference in latent heat of vaporization between the boiling brine and condensing steam, heat losses in the pre-heat exchangers, and energy loss of the system to the environment. The NOMAD produces steam for approximately 50 to 75 BTU/lb (shaft input at the compressor). The NOMAD is designed to remove soluble dissolved salts from wastewater. Insoluble or sparingly soluble material such as oil, suspended solids, or mineral compounds suspected of forming high quantities of scale (that cannot be managed with inhibitors) must be removed prior to treatment with the NOMAD or fouling can occur, which reduces both the capacity and recovery efficiency of the unit.

A primary innovation of the Fountain Quail technology involves circulating concentrate through the evaporator side of the evaporator exchanger. This circulating concentrate will contain a precisely controlled vapor fraction from 1% to 50%. With this controlled low vapor fraction, the concentrated fluid within the evaporator exchanger is subjected to an additional localized concentration factor of less than 1.1, avoiding localized precipitation of scaling compounds. As the vapor fraction increases while passing through the evaporator exchanger, the steam velocities increase significantly, reducing the risk of fouling. The temperature rise of the evaporating side of the evaporator exchanger is kept very low, resulting in low energy for compression. By adjusting the heat flux, the temperature of the wet surfaces for condensing and evaporating are maintained near that of the saturated steam condition. The type of boiling experienced will range from primarily forced convection to stable nucleate boiling of the wetted surfaces.

A secondary innovation of Fountain Quail technology involves the use of a highly efficient specialized plate and frame heat exchanger. The plate type exchanger offers a low, fixed static head and very low pressure drop on the concentrate circulating fluid or evaporating side, while providing a relatively high heat transfer coefficient. The heat flux can be easily adjusted by adding more surface area or plates in a given frame. The highly effective heat transfer coefficient allows the surface temperature to be very near to both fluid stream temperatures, reducing the risk of fouling. There are no hot or cold spots and no dead flow zones, which also lowers the risk of fouling or scaling. The compact size can be provided cost effectively with exotic alloy plates (i.e. titanium) to resist fluid corrosion and stress corrosion cracking, common to desalination type applications. The compact size also allows for modular construction, reducing both overall size and capital cost.

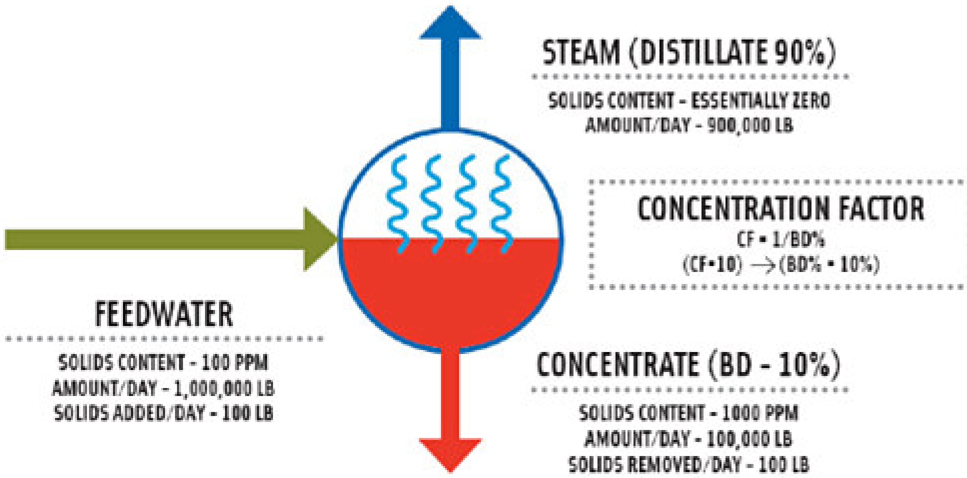
MVR Technical Details



NOMAD 2000 System

The NOMAD system has the ability to process highly variable oilfield wastewater and return to the producer approximately 85% of the feed volume as distilled freshwater that can be re-used. The NOMAD evaporator system is truly revolutionary. It is a system capable of addressing one of the greatest challenges of economically treating contaminated water that is the challenge posed by the variable nature and concentration of oilfield wastewater contaminants. Variations in the type and concentrations of contaminants will cause other technologies to fail, requiring frequent cleaning or recalibration. Wastewater generated from oil and gas operations is highly variable and therefore very difficult to treat. Having the capability to recycle this wastewater that would otherwise be wasted gives Aqua-Pure access to virtually untapped wastewater markets that have very few, if any, serious direct competitors except disposal.

Evaporation Theory

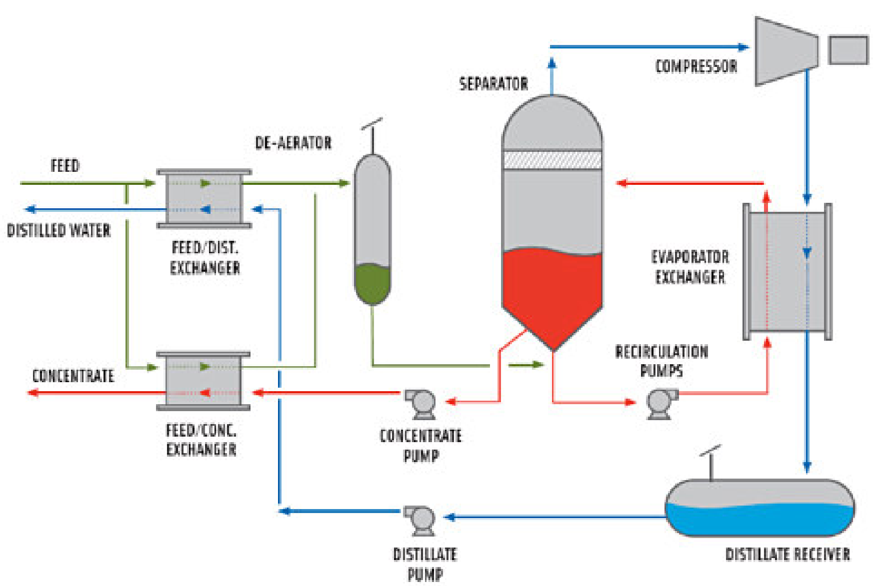


Evaporation is a method of producing pure distilled water from Feedwater containing dissolved solids. The Feed water is boiled to produce steam. When the water boils into steam it leaves behind all dissolved solid contaminants. The steam is condensed into pure distilled water.

In order to control the level of dissolved solids in the concentrated boiling fluid, a constant stream is drawn off. This is called concentrate. All of the dissolved solid contaminants that enter the system in the Feed water leave the system in the concentrate.

For Example, a Feedwater stream consisting of dissolved solids (Sodium Chloride (NaCl) Salt) will produce a distilled water stream and a stream of concentrated Sodium Chloride.

Mechanical Vapour Recompression Evaporation



Mechanical Vapour Recompression (MVR) Evaporation is a highly efficient process for evaporating distilled water from a feedwater containing dissolved solids. The NOMAD units are MVR Evaporators. In MVR systems, a compressor is used to add the energy required to boil feedwater into steam.

The Feedwater enters the NOMAD, breaks into two streams and flows through the Pre-Heat Exchangers. One Feedwater stream cross exchanges with the Distilled Water leaving the system and the other with the Concentrate leaving the system. Both the Distilled Water and Concentrate streams are very hot (near boiling) and transfer heat to the incoming Feedwater. The two hot Feedwater streams don't re-combine.

The hot Feedwater passes through a De-Aerator. In the De-Aerator, dissolved gases (such as Carbon Dioxide) in the Feedwater are released and vented. The hot de-aerated Feedwater then enters the Recirculation Loop.

The Recirculation Loop consists of boiling Concentrate flowing from the Separator to the Circulation Pump to the Evaporator Exchange and back to the Separator. The Circulation Pumps transfer the hot Concentrate from the Separator up through the Evaporator Exchange. In the Evaporator Exchanger, a portion of the hot Concentrate is boiled into steam. A mixture of Steam and boiling Concentrate exits the top of the Evaporator Exchanger and flows into the Separator.

Inside the Separator the Steam is separated from the boiling Concentrate. The Steam is drawn from the Separator with the Compressor. The Compressor boosts the pressure of the Steam and this causes the temperature of the Steam to go up. The high temperature, high pressure Steam is driven down through the Evaporator Exchanger. As the high temperature, high pressure Steam condenses into Distilled Water, it passes heat to the boiling Concentrate making it boil into Steam.

Hot Distilled Water flows from the bottom to the Evaporator Exchanger into the Distillate Receiver. The hot Distilled Water is pumped from the Distillate Receiver through the Feed/ Distillate Pre-Heat Exchanger where it cools down, passing heat to the incoming Feedwater. The cool Distillate Water then exits the system and flows to the Distillate Pit.

To prevent the Salt concentration from getting too high in the Recirculation Loop, a constant stream of boiling Concentrate is drawn from the Separator with the Concentrate Pump. The boiling Concentrate is pumped through the Feed/Concentrate Pre-Heat Exchanger where it cools down, passing heat to the incoming Feedwater. The cool Concentrate then exits the system and flows into the Concentrate storage tanks.

Boiling water on the stove requires 1000 BTU of energy to product 1 pound of Steam. MVR Evaporation uses a theoretical 50 BTU of energy to produce 1 pound of steam (5% of the energy of conventional evaporation).

The keys to the success for the technology are the cost of treatment has to be less than the cost of disposal to make the technology viable. The success of the technology is based on patented evaporator design allowing the unit to be portable, self sustaining and treating the water to allow reuse and recycle. Fountain Quail MVR Evaporators remain one of the only technologies operating in shale gas flowback recycling applications due to their high recovery efficiency and resistance to scaling and fouling. To date over 14,000,000 barrels of hydraulic fracturing flowback and produced waters have been recycled for re-use in the Barnett Shale. As other shale gas plays are being developed, Fountain Quail technology is being looked at as a leading example of effective shale gas water management technology. The equipment will be operational this year in the Barnett, Fayetteville and Marcellus Shales.

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