Condensate Recovery In Refinery Units

Introduction

Condensate recovery has been proven to be one of the most economical methods of water re-use for industrialized plants and systems. It is water generated by the condensation of steam from various processes such as steam trap discharge, heat recovery system and from equipment drivers (turbine exhaust). In older Oil Refineries, however, condensate is not always recovered for re-use as it generally becomes contaminated with hydrocarbon which can prove to be very problematic and expensive to treat before re-use within Utility systems.

Recovery of condensate in older Heavy Oil Refineries comes with even greater challenges than a modern oil Refinery. This paper seeks to address the methods employed at the Petroleum Company of Trinidad and Tobago (PETROTRIN), a Heavy Oil Refinery located in Trinidad and how simple strategies implemented can result in cost savings as well as minimize any negative environmental impacts and reduce overall water demand.

A Valuable Solvent

Water is one of the most valuable commodities in industries today. It is essential to life, has the ability to store energy and is known as the universal solvent. In the industrial world, water is used for a variety of purposes which include:

- Heat Transfer (coolant or preheat medium)
- As an additive to aid in dispersion
- Steam generation –
  - Motive steam
  - Stripping steam for process operations
  - Snuffing steam to ensure efficient burn of hydrocarbons at burners

In its natural state, water contains a considerable amount of impurities (organic and inorganic) which must be removed through various treating methods, prior to its usage. When not removed, the impurities may form deposits on heat transfer surfaces that may cause metal corrosion and/or reduce heat transfer rates, leading to overheating and loss of equipment integrity. (Water Treatment, Storage
& Blowdown For Steam Boilers n.d.). The determination of the water treating method to adopt for the removal of the impurities depends on:

- The types of impurities in the water
- The intended use of the treated water
- Environmental discharge parameters for the disposal of the effluent waste generated from treating.

Therefore, in order to ensure an adequate supply of high quality water for industrial use, the following must be implemented:

- Purification and conditioning systems prior to use
- Wastewater treatment systems to eliminate/minimize any potential environmental impact
- Conservation and reuse of water (Betz Laboratories, Inc 1991).

In the Petrotrin Refinery, emphasis is continually placed on implementing the first two recommendations. Due to the high potential for hydrocarbon contamination, the company remains committed to identifying appropriate solutions to be better positioned to institute and sustain conservation and reuse. It is noted that with the implementation of systems for Conservation and reuse of water encourages optimization of the process stream such that the plant engineer’s objectives focuses on ways to:

- Reduce the quantity of raw material and energy being consumed
- Minimize waste generated through efficient use of resources
- Recover useful material from waste streams
- Treat any residual waste such that it can be converted to an environmentally acceptable form prior to disposal

To this end, savings to implement water recovery and reuse schemes have been realized.

**Condensate Generation & Recovery**

Steam (water in vapor form) carries a significant quantum of energy which can be converted and used for various purposes. Steam generated in the Petrotrin Refinery is used for:

- Generation of Electric Power
- Motive Steam for drivers of equipment such as pumps, compressors and fans
- A heating medium
- Enhancing the process (in the form of stripping steam)
Though the quality (specifically temperature and pressure) of steam varies for the specific purpose, when 1 kilogram (kg) of steam has been used and condenses, 1 kg of water will be generated. This condensed water, which contains almost no Total Dissolved Solids (TDS) and impurities, is known as condensate and is of equivalent quality as distilled water.

Within the process units at PETROTRIN, condensate is usually accumulated and stored in atmospheric tanks, thus having a temperature below the boiling point of water (100 deg C). Improved operation with an emphasis to minimize/eliminate hydrocarbon contamination has resulted in condensate which can be recovered for reuse within the Utility Plants. This has been the case with the recently revamped and newly installed process plants within Petrotrin Refinery; in particular the new C3/C4 Alkylation Unit and Sulphuric Acid Regeneration (Alky/Acid) Plants along with the upgraded Fluidized Catalytic Cracking Unit and Gas Concentration Unit (FCCU/GCX).

Materials (hydrocarbons, steam, water, slurry mixes) are transported throughout the Refinery via a network of piping. However, minimal infrastructure existed for condensate recovery and reuse within the Utility Plant - the Centralized Steam Plant (CSP). Historically, condensate generated by the various process plants would become contaminated with hydrocarbon. FCCU/GCX and Alky/Acid units were designed to generated approximately 550 Imperial Gallons Per Minute (iGPM) of clean, uncontaminated condensate, which due to lack of condensate recovery systems, would be routed to the API/Oil Water Separator and then to the nearest water course as shown in Figure 1.

**Figure 1 – Condensate Disposal**
By routing this high quality water stream to drain the Refinery had to replace unrecovered condensate in the Boiler Feed Water (BFW) system by cold make-up water. This resulted in additional costs due to water treatment chemicals and fuel cost. Further to which, unrecovered condensate must be replaced by make-up water, incurring water charges from the water supplier. Costs associated with the disposal of condensate has been estimated at $3.00 US/MiGal (thousand imperial gallons), with costs of condensate being equated to the cost given to undeaerated BFW due to their equivalent quality (Figure 2).

<table>
<thead>
<tr>
<th>Quantity of Condensate Generated</th>
<th>550 iGPM</th>
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</thead>
<tbody>
<tr>
<td>Quantity of Condensate to be discarded daily</td>
<td>792 MiGal</td>
</tr>
<tr>
<td>Cost of Unde aerated Boiler Feed Water</td>
<td>$ 3.00 US/MiGal</td>
</tr>
<tr>
<td>Daily losses due to unrecovered Condensate</td>
<td>$ 2,376.00 USD</td>
</tr>
<tr>
<td>Projected Yearly Losses</td>
<td>$ 867,240.00 USD</td>
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</tbody>
</table>

**Figure 2 – Cost Benefits Of Recovering Condensate**

**Realized Benefits**

Implementing a condensate recovery and re-use system will result in significant benefits to the operations of the Utility unit which includes reduction of:

- Water charges due to reduced water demand
- Fuel costs as water will be reused in place of BFW
- Blowdown from steam generators and boilers
- Energy losses
- Chemical treatment costs

Therefore, incorporating the requisite infrastructure for an effective condensate recovery system is economically justified. The design of a condensate system was conducted through a robust review of various utility plants. One of the Utility water treating plants which is in close proximity to the FCCU/GCX and Alky/Acid Plants is the Eastern Water Treating Plant (EWTP). This plant treats raw water for BFW preparation as well as for cooling tower water make-up. It is also linked by a major pipeline to the CSP which is approximately 2km of piping away.

The EWTP condensate tanks used in the cooling tower water make-up system were available for use in the scheme wherein, with the installation of pipework and pumping facilities condensate can be routed to the required location. FCCU/GCX and Alky/Acid though being in close proximity to EWTP are a
comparable distance away from CSP. As such, the condensate generated from these units can easily be routed to EWTP. Utilizing the existing interconnecting pipeline and with the installation of new pump-sets, the recovered condensate can be routed directly to CSP as shown in Figure 3.

![Figure 3 – Condensate Recovery System](image)

In the event that the condensate recovery system malfunctions (pump failure, loss of power), the condensate can be recovered into a water system of a lower quality as identified below:

- Treated filtered water which will be used for BFW preparation
- Treated unfiltered water which is used as make-up for cooling towers

The cost of either of these qualities is estimated at $2.60 US/MiGal.

As the majority of condensate is generated on the hydrocarbon process units, the likelihood (though significantly minimized) exists for it to become contaminated. Consequently, future consideration is to be given to the evaluation and design of a treating system beyond the traditional injection of chemicals.

**Conclusion**

Condensate systems at PETROTRIN traditionally focused on the removal of oil from water prior to discharge to drains and oily water sewers. Advances in technology, upgrades of process and plants and stringent environmental regulations have resulted in systems where contamination by hydrocarbon is an abnormal occurrence. The generation of clean condensate and its recovery is one means to improve energy efficiency as well as benefit from cost savings due to the reduced water consumptions via reuse, even if it is not recovered directly into a Boiler Feed Water system.
Bibliography

