PETROLEUM

BestPractices
Technical Case Study

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Installation of Reverse Osmosis Unit Reduces Refinery Energy Consumption

Benefits

- Lower energy costs because of fewer boiler blowdowns
- Lower maintenance costs
- Lower waste disposal costs
- Total annual savings of $200,000

Applications

Naturally occurring minerals can foul the tubes in steam boilers, resulting in reduced boiler efficiency and run length. Removal of these minerals is essential for efficient boiler operation. At the Flying J Petroleum Refinery, a new reverse osmosis unit has proven more reliable than the hot lime softener it replaced. This new process also requires less operator attention.

Summary

In August 1998, the Flying J Petroleum Refinery replaced its hot lime softener, which removes hardness and alkalinity from boiler feed water, with a reverse osmosis unit. The benefits of this replacement project include lower energy costs from reduced boiler blowdown requirements, as well as lower maintenance costs from the elimination of handling lime slurry and its associated cleaning and plugging problems. Another benefit is lower waste disposal costs because no lime is discarded. The total savings are estimated to reach $200,000 annually.

Plant Overview

The Flying J Petroleum Refinery, located in Salt Lake City, Utah, processes 25,000 barrels per day (BPD) of crude oil. The new reverse osmosis unit provides make-up water to four natural-gas-fired package boilers and six waste-heat boilers.

Project Overview

Naturally occurring minerals in the city water supply, such as calcium, magnesium, and silica, tend to precipitate out in the refinery's steam boilers, resulting in tube

Cleaner Water Increases Efficiency of Flying J's Boilers

fouling that significantly reduces boiler efficiency and run length. Removal of these minerals is critical to efficient boiler operation.

Hot lime softening is a two-stage process. First, ambient temperature city water is mixed with steam in the upper chamber of the vessel. This process removes oxygen entrained in the water and preheats the water to around 200° F, the temperature required to effectively react with lime. A lime slurry (calcium hydroxide) is circulated through the lower chamber of the vessel, where it elevates the pH of the hot water to 10+. The calcium and carbonate alkalinity present in the city water react to form calcium carbonate and precipitate. The magnesium in the water reacts with the hydroxide, precipitating as magnesium hydroxide. Silica does not react, but adsorbs on the other precipitated solids and is removed with the blowdown. Chemicals are added to flocculate (to form lumps or masses of) the small particles and increase the settling rate.

The treated water then flows through a filter to remove any solid carry-over. The remaining hardness is removed by passing the water through a sodium zeolite resin softener. The zeolite softeners remove hardness by exchanging calcium and magnesium ions in the water for sodium ions contained on the resin. The softeners are periodically backwashed with saltwater to displace the calcium and magnesium ions with fresh sodium ions.

In the reverse osmosis process, city water is first passed through dual filters containing several layers of progressively finer and denser material. This filtration process removes suspended matter from the water. Chemicals are added to the water to control the potential for silica to scale the reverse osmosis membranes and to destroy any free chlorine, which can damage the membranes.

Computerized Operation Optimizes Control of the Process

Reverse Osmosis Unit in Operation

The water pressure is increased to approximately 300 psig before entering the reverse osmosis unit. Reverse osmosis is essentially a filtration process at the molecular level. The water pressure forces the water through a semi-permeable membrane, while retarding the passage of the dissolved solids. The water containing the dissolved solids, called the concentrate, leaves the unit and is discarded. The clean water product is then sent through the zeolite softeners for final polishing before entering the boilers.

The reverse osmosis membranes require semi-annual cleaning and periodic replacement to maintain efficient performance.

Project Implementation

The Flying J Petroleum Refinery had been looking for a replacement process for hot lime softening since the late 1980s. After a review of the literature, reverse osmosis was identified as a potential replacement. The project began in late 1995 with a study of the available reverse osmosis technology. Flying J selected Culligan International to design and build the major components of the unit. The equipment was skid mounted at Culligan's facility in Northbrook, Illinois, and then shipped to the refinery. Flying J personnel completed the on-site electrical and mechanical installation, and the unit began operation in August of 1998. The project was implemented at a total cost of approximately $350,000.

Results

The most significant benefit of the replacement project has been the reduction in boiler blowdown from 7.5 cycles (13.3 percent of steam produced) to 65 cycles (1.5 percent of steam produced). At today's high fuel cost, this results in savings of $165,000 per year. Other savings, including boiler treatment chemicals ($36,000 per year), maintenance ($20,000 per year) and waste disposal ($4,300 per year), result in total net savings of approximately $200,000 per year. The reverse osmosis unit has proven to be more reliable than the hot lime softener and requires less operator attention. New costs include the cleaning of the reverse osmosis membranes every 6 months, periodic replacement of the membranes, and additional electric power for the reverse osmosis unit pumps.

Industry of the Future—Petroleum

Petroleum is one of nine energy- and waste-intensive industries that is participating with the U.S. Department of Energy's (DOE) Office of Industrial Technologies' Industries of the Future initiative. Using an industry-defined vision of the petroleum industry in the year 2020, the industry and DOE are using this strategy to build collaborations to develop and deploy technologies crucial to the industry's future.

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BestPractices is part of the Office of Industrial Technologies' (OIT's) Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together the best-available and emerging technologies and practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

BestPractices focuses on plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers.

Project Partners

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