PetroSorb™

Condensate Water Treatment with Activated Carbon

Introduction

The conservation of water is a primary concern of all industrial users of this precious resource. This is possible in a variety of ways, but the most efficient is to operate closed-loop systems, such as those used in the reclamation of steam condensate for re-use as boiler feed water.

Within the petrochemicals and power generation industries it is common practice to recycle condensed steam for use as boiler feed water. Such processes improve plant economics offering a ready source of already heated water, often >80°C, that, by being a condensate, does not typically require further demineralization by ion exchange. An additional advantage to this recycling of the condensate is that avoids environmental issues associated with the disposal of contaminated water.

However, when recycled condensates are to be used as boiler feed water for medium or high pressure boilers for process or power generation applications a down stream ion exchange unit must be installed in order to prevent trace quantities of minerals leached from the activated carbon reducing the efficiency of boilers and turbines.

Additionally, condensate feed waters frequently contain a wide variety of hydrocarbon contaminants that are entrained with the water from process equipment e.g., leaking seals on rotating equipment such as pumps, or from chance contamination by associated hydrocarbon process streams. This hydrocarbon contamination must be removed from boiler feed waters to avoid coking of these contaminants on heating in the boiler producing carbon deposition within the boiler tubes that will reduce heat transfer and overall boiler efficiency. Hydrocarbon concentrations may be in excess of 6 mgL^{-1} but are more typically 2 to 4 mgL^{-1}

In flash boilers and welded water tube boilers coking occurs on the surfaces where heat flow is highest causing tubes to overheat and distort or burst. For boilers using expanded joints, the problem may be worse as the oil quickly penetrates the joint and causing the boiler to leak. Boiler decoking can be achieved by sand blasting. However refinery process boilers frequently require more extensive decoking operations requiring the plant to be taken off line and boilers burned out with high temperature oxygen or air. Thus, keeping the boiler clean of hydrocarbons becomes a major maintenance task.

Condensate typically contains < 5 mgL^{-1} of hydrocarbons and at these concentrations active carbon is an extremely efficient adsorption medium for such entrained hydrocarbons and is widely used to treat condensate achieving very high removal efficiencies, frequently greater than 95% removal. At concentrations greater than ~ 6mgL^{-1} carbon retains its effectiveness but additional process equipment may be required, e.g. coalescers or pre-filter beds, to prevent premature fouling of the carbon adsorbent by oil droplets.

Extensive research and plant operational experience has shown that Jacobi Carbons PetroSorb^{TM} HS-D grade is the most suitable adsorbent for this application offering hydrocarbon uptakes of ~30wt % to saturation.

PROCESS DESCRIPTION

This section describes a generic refinery scale condensate treatment process. The system described utilizes twin adsorbers removing ca. 2 - 4 mgL^{-1} (saturation level) of dissolved oil from hot condensate at 45°C upstream of an ion exchange resin (IER) treatment bed feeding an 85°C upstream heat exchanger / boiler return loop.

Principal Process parameters were:

• volume flow rate:	50 m^3 $hour^{-1}$ (total)
• carbon filters:	2x10.5 m^3 adsorbers in series (21m^3 total)
• contact time:	2x12 mins (24 mins total)
• concentration oil:	
inlet:	>2.0 mgL^{-1}
outlet:	<0.18 mgL^{-1}
• SiO2 ex GAC:	<0.05 mgL^{-1}
• SiO2 ex IER:	<0.03 mgL^{-1} (mean value)

Start-up

Following filling of the activated carbon into the adsorber initial washing is undertaken with hot condensate in down flow at a rate of 2 m^3 condensate/ m^3 activated carbon per hour for a period of 24 hours. The effluent from the initial washing is discarded to drain.

Following this initial washing stage the filter is backwashed in order to classify the bed. The sequence of washing may be summarized as below:

- 30 min. of backwashing at a bed expansion or 30%
- 20 min. of backwashing at a bed expansion or 20%
- 5 min. of backwashing at a bed expansion or 15%
- 5 min. of backwashing at a bed expansion or 10%

Operation

After completing the backwashing cycle, filtration in the down flow direction may commence. Optimum process flow rate should be controlled to maintain design contact time and the silicon content of the effluent water should be monitored.

If the initial silica measurements in the effluent water do not comply with the plant operational requirements additional washing with hot condensate, in down flow, at a rate of 2m^3 condensate per m^3 activated carbon per hour for a further period of 48 hours (96 bed volumes of hot condensate) must be undertaken.

The effluent from the second washing should then be discarded to drain. Backwashing may then be repeated as detailed previously and as deemed necessary.

Should filter head loss become excessive adsorbers may be backwashed to 30% expansion as in above.

Operational Issues

Principal operational issues typically concern hydrocarbon loads and silica leach from the activated carbon.

As described previously should hydrocarbon loads exceed 5mgL^{-1}, the process stream should be pre-filtered to prevent premature fouling of the carbon adsorbent by liquid oil droplets. This filtration should use Anthracite or similar carbonaceous media as the recommended pre-filter media. It is important to note that sand should not be used as a filtration media as it will markedly increase the silica content of the condensate (see below).

When recycled condensates are to be used as boiler feed water for medium or high pressure boilers a downstream ion exchange unit must be installed in order to prevent trace quantities of minerals leached from the activated carbon affecting the efficiency of boilers and turbines. It is the responsibility of the plant operator to ensure that the amount of silica leaching from the activated carbon is within the required limits prior to commencing start-up of the boiler/turbine system.

Activated Carbon contains silicon in its ash and this must be washed out during the start-up procedure to the satisfaction of the plant operator, in order to avoid silica leach that is detrimental to high-pressure boilers and power generating turbine systems. Deposition of silica in boiler tubes creates similar heat exchanger problems to coking from oil in condensate.

Deposition of silica on turbine blades in power generation equipment is much more problematic as it can result in unbalancing the high-speed rotation of the turbine and can induce catastrophic axle failure.

PetroSorb™ HS-D is specially prepared activated carbon subject to multiple washing, to remove soluble silica ash and is characterized by very low silica release into condensate (see above) after initial back washing and is the Jacobi Carbons grade recommended for condensate treatment systems.

ACTIVE CARBONS FOR REMOVAL OF HYDROCARBONS FROM CONDENSATE.

Jacobi Carbons PetroSorb™ HS-D

PetroSorb™ HS-D is a washed high purity high activity granular activated carbon manufactured by steam activation from carefully selected coconut shell charcoal. This grade is particularly suited for ultra-pure water treatment systems requiring waters of low conductivity and exceptionally high purity. This material is also specifically recommended for the removal of heavy hydrocarbons from condensates. The washing process reduces soluble silica (SiO_2) from the matrix of the activated carbon to prevent leaching into the condensate.

The typical properties of PetroSorb™ HS-D are as follows:

• Iodine number	mg g^{-1}	1050
• BET Surface area	m^2 g^{-1}	1100
• Apparent density	kg m^{-3}	510
• Bed density, backwashed and drained	kg m^{-3}	435
• Total ash content	wt %	0.5
• Si Leach after 10 bv	mgL^{-1}	0.1
• Moisture content - as packed	wt %	4.0
• Acid soluble matter	wt %	0.01
• pH		6
• Ball-pan hardness number	%	99

When used for removal of hydrocarbons from condensate PetroSorb™ HS-D is characterized by a large adsorptive capacity for oil, at approximately 30% uptake by weight, and levels of silica release into condensate that are much lower than that typical for standard coconut carbons.

COMPARISON OF PETROSORB™ HS-D, PELLETISED PEAT AND COAL BASED ACTIVATED CARBONS

Table 1. Comparison of PetroSorb™ HS-D and Peat and Coal Based Carbons

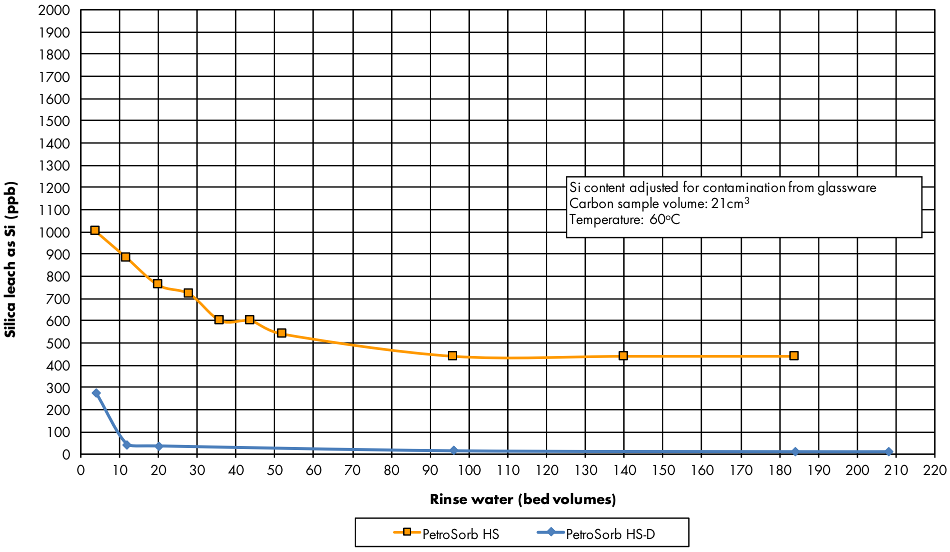
Typical Property		PetroSorb™ HS-D	0.8 mm Peat Pellet	Acid Washed 0.8mm Coal Pellet
Backwashed density	kgm^{-3}	435	380	380
Ash	wt %	0.5	8	5
Iodine no.	mg g^{-1}	1050	1050	1050
Surface area	m^2 g^{-1}	1100	850	900
Hardness	%	99	94	92
Moisture	wt %	4	2	2

The above table allows a comparison of the physical properties of PetroSorb™ HS-D and competitor coal based pelletised carbons at 0.8 mm diameter (both standard and acid washed grades) based on commercially available data. PetroSorb™ HS-D offers distinct advantages over such coal & peat based products by being denser, harder and lower in ash.

As PetroSorb™ HS-D possesses a 20% greater density than coal & peat based pelletised products an adsorber loaded with PetroSorb™ HS-D will exhibit a greater hydrocarbon capacity overall as it contains a corresponding 20% more carbon. The high hardness of the PetroSorb™ HS-D results in significantly less attrition of the carbon in the adsorber and lower release of fine carbon particles into the condensate during adsorber operation.

However, most importantly in respect of condensate treatment applications, the higher purity of the PetroSorb™ HS-D (75% less ash than the acid washed coal & peat pellets) means that the product offers much less silica leach into condensate significantly reducing rinsing requirements and reducing the risk of potential boiler or turbine problems. Coal and peat based carbons produce significantly greater silica leach than coconut based carbon products as their ash composition contains a large alumino-silicate content and even after acid washing this can only be reduced to ~3% residual ash (see Table 1).

Figure 1 - Silica leach of PetroSorb™ HS-D in comparison to standard acid washed coconut shell carbons



Evaluation of the silica release of PetroSorb™ HS-D even when compared to standard commercially available acid washed coconut carbons has shown a significantly lower silica release even during initial rinsing operations as a part of standard commissioning procedures. Plant operational experience has confirmed that PetroSorb™ HS-D requires significantly less rinsing than the acid washed coal based pellet products to achieve required silica release levels in order to put the GAC columns into service.

CONCLUSIONS

PetroSorb™ HS-D provides the following advantages:

1. Maximum filter life due to combination of high activity and optimum density
2. Minimum losses in backwashing due to greater hardness
3. Minimal silica leach at typical condensate temperatures, e.g. 80°C
4. Minimal residual ash content – much reduced mineral leach

Acknowledgement: This paper is authored by Dr Steven Ragan, Research and Development Director of Jacobi Carbons Group.