



High Efficiency Coalescers Increase On-Line Process Analyzer Sensor Reliability

Presented at the Analysis Division 48th Annual Spring Symposium,
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by

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Abstract

On-line process analyzers have become common place in industrial plants and are becoming more complex and numerous each year. One of the most critical issues with the use of on-line sensors is their vulnerability to fouling and the potential harmful outcomes of inaccurate measurements such as non optimized process control leading to loss of revenue. Also of concern is the need for costly replacement parts due to corrosion and maintenance related to frequent repairs or cleanings. Advances in separation technology of liquid / gas coalescers and liquid / liquid coalescers and their application to sensor protection are presented. The use of specially engineered polymeric

media has advanced the state of the art for separating liquid aerosols from gases and breaking emulsions in liquid systems. Separation mechanisms in the newly developed technology are described along with how this technology is applied to analyzer protection. Installations of this separation technology include protection of near infra red sensors in gasoline blending, density meters and gas chromatography analyzers in fuel gas, and sensors used to monitor sour water. Case histories from a European Refinery and Canadian Refinery are presented covering the installation details and cost-benefit analysis.

Introduction

Sampling systems for process analyzers consist of all the equipment required to present an analyzer with a clean, representative sample of a fluid stream, and to dispose of that sample once processed. When the analyzer is part of an automatic control loop, the reliability of the sampling system is as important as the reliability of the analyzer, or the control equipment. Sampling systems have several functions. The sample must be withdrawn from the process, transported, conditioned, introduced into the analyzer, then disposed of upon completion of the analysis. A common problem in sample-system design is the lack of representative, "real" time information concerning the properties of the process fluid at the sampling point.

Another common problem is the lack of understanding regarding the level of fluid clarification required so that the analyzer may process the sample without malfunctioning for

long periods of time. Some fluid streams may require such extreme conditioning and treating, such that the sampling system and its pre-conditioning train become miniature on-line processing plants. These systems pose many of the same fabrication, reliability, and operating problems as small-scale pilot plants – except that the sampling system typically must operate reliably for much longer periods of time. When installing an analyzer protection system, careful consideration should be made to avoid removal (by either physical separation or adsorption) of the components that are intended to be measured as this could lead to serious errors.

Sample conditioning usually involves the removal of contaminants or some deleterious component from the sample mixture and/or the adjustment of temperature, pressure and flow rate of the sample to parameters acceptable to the analyzer. Some of the most common

contaminants that must be removed are rust, scale, corrosion products, deposits due to chemical reactions, water or some other aqueous phase, tars, and gums. The presence of these contaminants even in trace quantities can lead to analyzer failure. Water, for example, can damage a gas chromatographic column packing or mask the C-H absorbency in the infra-red spectrum. High efficiency coalescer technology has been applied successfully for the protection of near infra-red (NIR), gas

chromatography (GC), pH probes, sulfur in gasoline analyzers, density meters, motor octane number (MON), research octane number (RON), and color analyzers.

In this paper, application of novel high efficiency coalescing technology is discussed along with critical factors for successfully employing this sample conditioning option in fast loop sampling systems.

Coalescer Technology

Coalescers are designed especially to separate either liquid aerosols from a gas stream or to break liquid / liquid emulsions. They can be constructed from fibers made of various materials including glass, metal, polymers and fluoropolymers. The coalescer media can be configured as pleated sheets or as a depth type, but have in common a pore gradient that goes from smaller to larger sizes in the flow direction and an outer coarse sleeve material to complete the coalescing process. In principle, coalescers can operate indefinitely as long as they are not exposed to solid contaminants. In practice, coalescer systems, with proper pre-filtration, typically achieve service lives varying from six months to two years. A schematic of the coalescing process showing the growth or coalescence of droplets as they pass through the coalescer medium is given below in Figure 1.

Coalescing systems operate in three stages: separation of solids, coalescence of small drops into large drops, and finally the separation of the large coalesced drops from the purified continuous stream. During the coalescing process the inlet drop sizes are in the sub micron to low micron size range and after passing through the coalescer are in the millimeter size range. Both liquid / gas and liquid / liquid coalescer technology have been successfully applied to analyzer technology.

Liquid / Gas Coalescers

Liquid / gas coalescers are the latest development in the history of liquid / gas separation units. Their performance is superior to knock-out drums, vane separators, mesh pads, and combinations of filter separators and vane or mesh packs. These older devices rely on inertial separation mechanisms, and work well for larger

Figure 1:
Coalescing
in the Medium

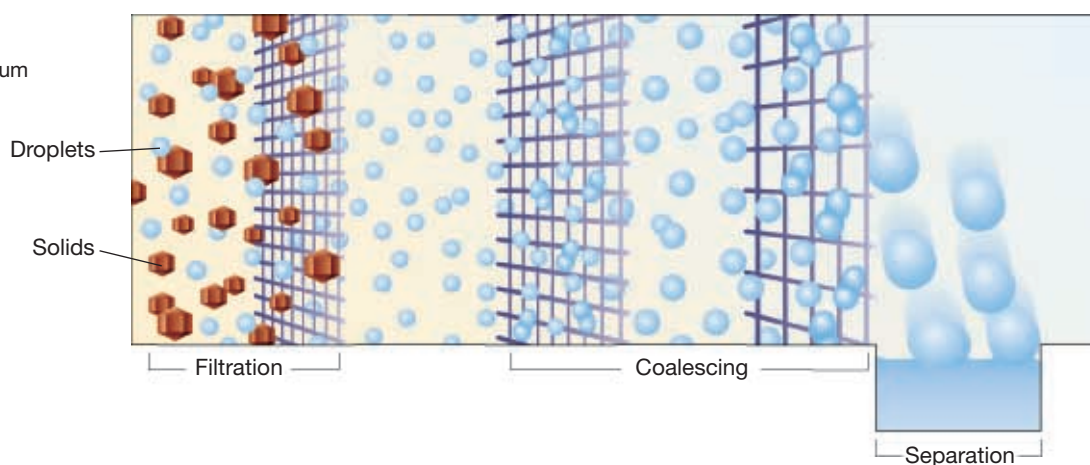
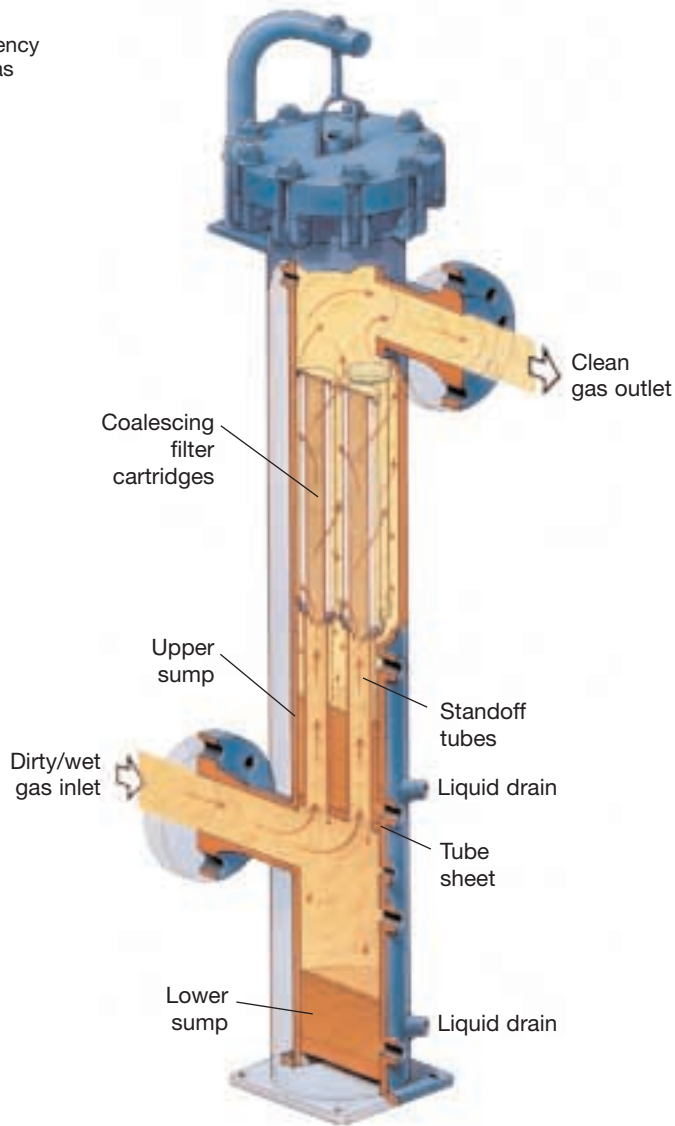


Figure 2:
High Efficiency
Liquid / Gas
Coalescer



aerosol droplets (>5 micron), but lose efficiency at reduced flow rates.

High efficiency, vertical liquid / gas coalescers have been used extensively in gas processing in the last decade. They offer the advantage of increased removal capability of fine droplets (down to 0.3 micron in size and to levels as low as 3 ppb), and are able to operate efficiently at low flow rates. A recent innovation in liquid / gas coalescer design is to use a surface treatment^{1,2} to prevent the wetting of the coalescer media with the aerosol liquids, thereby increasing the allowable flux, decreasing fouling tendency, and decreasing pressure drop losses.

A schematic of an industrial size liquid / gas coalescer system is provided in Figure 2.

Liquid / Liquid Coalescers

Liquid / liquid coalescer systems are used extensively to dry jet fuel and are finding increasing applications for refinery and chemical process streams.³⁻⁷ These systems can be divided into two broad categories: vertical with separator stage, and horizontal with gravity separation. Schematics of the vertical and horizontal coalescer configurations are given in Figures 3-4.

Both configurations employ a coalescence stage. In the vertical configuration, a hydrophobic barrier repels the coalesced aqueous drops in a second separation stage. In the horizontal configuration, a settling zone achieves separation of the coalesced drops. The vertical configuration is used to separate water from hydrocarbons when the interfacial tension is greater than 3 dyne/cm. At lower interfacial tensions, or for oil from water separations, the horizontal configuration is used. Typically, the process stream leaving the liquid / liquid coalescer will have a concentration of less than 15 ppmv of free dispersed contaminant phase.

Traditional coalescers have used glass fiber media, which works well for emulsions that have interfacial tensions greater than 20 dyne/cm. New coalescer media, constructed with novel formulated polymers and fluoropolymers⁵ are effective for emulsions having interfacial tensions as low as 0.5 dyne/cm. An improved design of the vertical liquid / liquid coalescer has been to stack the coalescers on top of the separators, as opposed to older designs that had the separators located in a separate section of the housing. This new design improved the flow distribution, and thereby increased the separator utilization.

Figure 3:
Vertical Liquid /
Liquid Coalescer

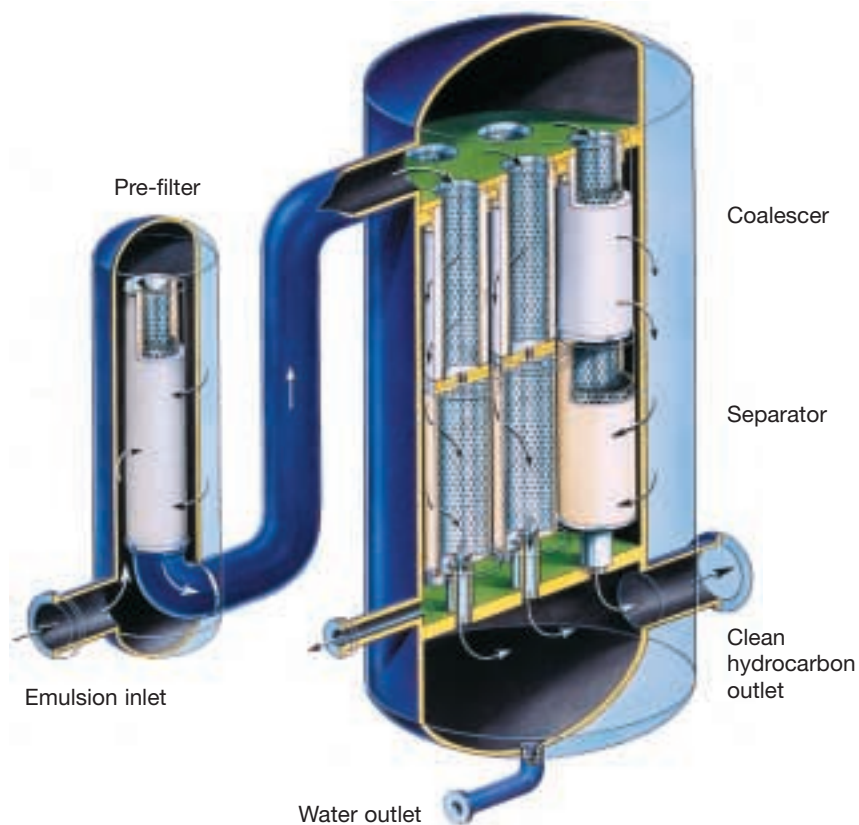
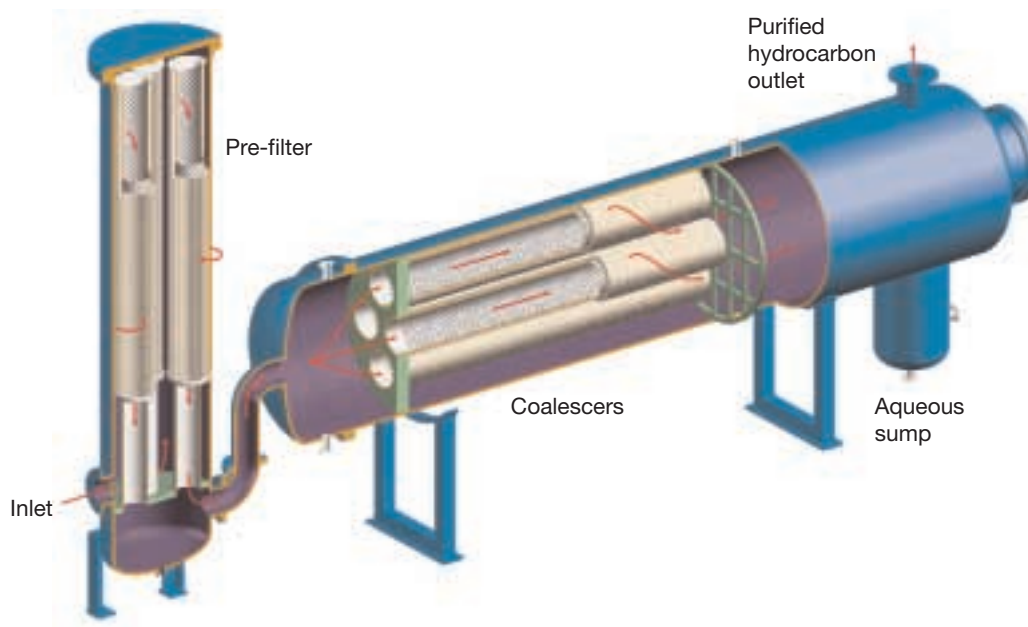


Figure 4:
Horizontal
Liquid / Liquid
Coalescer System



Surfactant

Problems Created at Solid / Liquid and Liquid / Liquid Interfaces

Surfactants are present naturally in crude oil and as a result are in refined petroleum products. During the oxidation process and the caustic re-circulation in sulfur removal processes, surfactants can be concentrated to high levels.

Surfactants that have been identified in caustic treaters include sulfides, mercaptides, naphthenic acids, cresylic acids and phenol homologs.⁸ Petroleum naphtha sulfonates have also been identified as naturally occurring petroleum surfactants that are especially detrimental to conventional glass fiber

coalescers.⁹ The surfactants can adsorb at the solid / liquid interface (coalescer fibers) or at the liquid / liquid interface (water/oil).

When surfactants concentrate on the coalescer fibers this is known as “disarming”. The coalescer fibers are shielded from the passing aqueous droplets and this results in poor separation efficiency. Generally, the disarming phenomenon does not occur unless the interfacial tension between the water and fuel is less than 20 dyne/cm. When specially formulated polymeric coalescer medium was used instead of glass fiber, disarming was not observed.^{5,6} The coalescing performance of a polymeric medium

can be greatly enhanced by modification of surface properties that cannot be accomplished with glass fiber medium.

Surfactants can also concentrate at the water/fuel interface and this can lead to very small droplets and stable emulsions. A survey of caustic-hydrocarbon emulsions showed the interfacial tensions varied from 0.5 dyne/cm to 12.4 dyne/cm.³ To separate these types of emulsions, special consideration must be applied to the pore size and distribution in the coalescer media to intercept and coalesce the small droplets.

Sampling System Configuration

In order to apply coalescing technology to analyzer protection, scaled down versions of the industrial systems are required. The use of fast loop sampling systems are critical to ensure that representative (fresh) fluid is analyzed for real time optimal process control. Here, a high flow rate is maintained in a loop that goes through the pre-filter and coalescer and is then re-routed back to the process. A smaller stream of the purified fluid is drawn off for analysis.

An important distinction between the use of coalescers in analyzer protection and full scale industrial use is that the contaminant phase is

re-routed back into the process stream. This configuration allows for less instrumentation as it is not critical to monitor the separated contaminant fluid for level control since it is purged continuously back into the process. This leads to a different flow path in the coalescer housing whereby the fast loop flow rate is passing out through the normal collection sump connections back to the process, while a smaller sampling flow is leaving the normal main outlet port. Representative schematics of a fast loop sampling system for a liquid / liquid coalescer system and a liquid / gas coalescer system are provided below in Figures 5-6.

Figure 5:
Fast Loop for
Liquid / Liquid
Coalescer

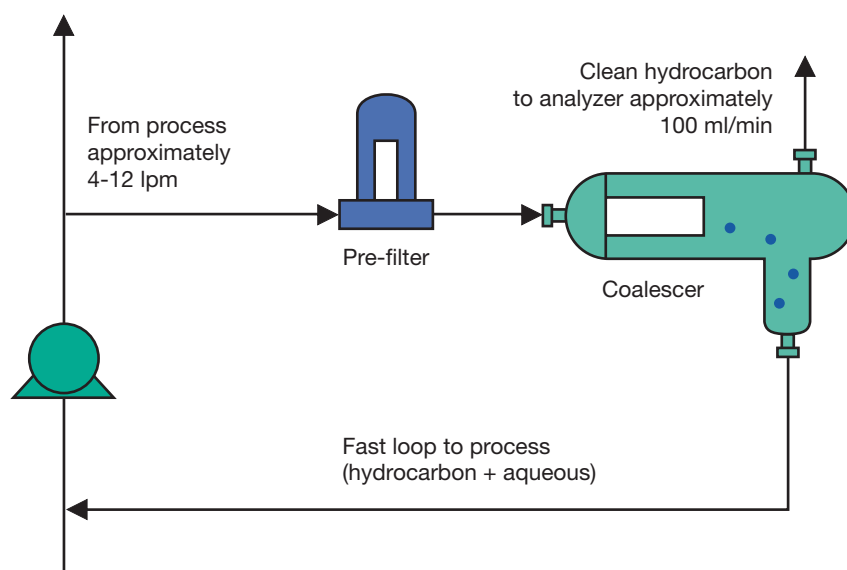
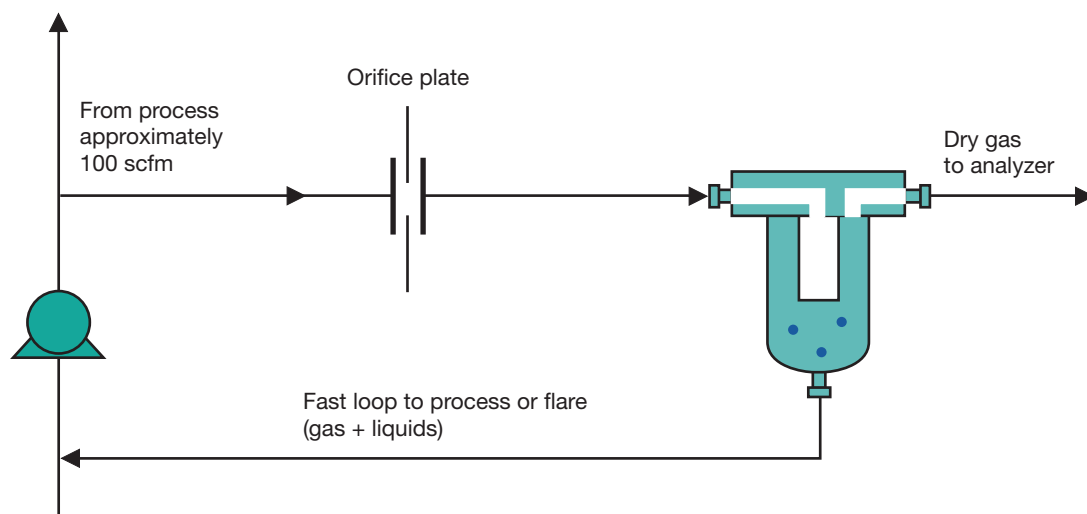


Figure 6:
Fast loop for
Liquid / Gas
Coalescer



Case History - European Refinery

Background / Problem

At a European Refinery, the presence of caustic water in the sampling system caused fouling of the on-line NIR analyzers for gasoline blending. The hydrocarbon stream was composed of caustic treated heavy cat naphtha (HCN) and light cat naphtha (LCN). The fast loop flow rate was 1.3 lpm (0.35 gpm) at an operating pressure of 10 barg (145 psig), and an operating temperature that varied from 5-35 °C (41-95 °F) with an interfacial tension of 10 dyne/cm.

Many gaseous and liquid compounds absorb infrared radiation to some degree. The degree of absorption at specific wavelengths depends on molecular structure and concentration. Process instruments generally are of the non-dispersive type. That is, the detector is exposed to a wide-wavelength band of radiation. This contrasts with the normal laboratory instrument, which uses a scanning monochromator to isolate successive narrow-wavelength bands. The main components of a process instrument are the radiation source, sample cell and detector. The radiation source is commonly a heated wire, which yields radiation over the analytically useful portion of the infrared spectrum. The main requirement is stability of emission. The radiation source window was being fouled by salt deposits from the caustic water that led to issues with the emission stability.

The refinery controls the gasoline blending by means of both a feed-forward loop and a feed-back loop. The feed-back loop is in an analyzer house and the refinery had managed to combat the problem of salt fouling by a series of sample conditioning steps. The feed-back sample passed through a 70 µm nominal filter and was cooled by means of a Vortex cooler followed by a low efficiency coalescer. Post coalescing, the stream would go through a 0.5 µm PTFE hydrophobic membrane filter to block and reject water. A final heating stage was employed to dissolve any remaining aqueous phase before the sample was introduced into the NIR analyzer.

Such extensive conditioning of the feed-forward loop, however, was not possible as the analyzer was on-site immediately after gasoline storage tanks with no facilities to readily heat or cool the streams. These analyzers were being bypassed due to salt fouling, and as a result, the refinery was relying only on feed-back control. Revenue losses were considered significant due to inaccurate blending. The NIR analyzer was used to determine the octane number and without accurate readings, the blending did not result in the optimum octane values.

Solution

The refinery decided to protect four naphtha blending stream NIR analyzers using high efficiency liquid / liquid coalescers. Each system contained a single liquid / liquid coalescer constructed of fluoropolymer media that was 152 mm (6 inch) in length by 64 mm (2.75 inch) diameter. The coalescer had a maximum rated flow of 19 lpm (5 gpm). The coalescer housing was made of 316 L stainless steel with a pressure rating of 16 barg (240 psig) and hold up volume of 4 liter (1.06 gallon). A nylon depth style filter with an absolute rating of 10 µm was used to protect the coalescer. The pre-filter was 127 mm (5 inch) in length by 64 mm (2.5 inch) diameter. The pre-filter housing was made of 316 L stainless steel with a pressure rating of 16 barg (240 psig) and hold up volume of 2 liter (0.53 gallon).

The installation of the high efficiency liquid / liquid coalescer sample conditioning system was found to surpass other traditional technology that had been previously employed in terms of efficiency and effectiveness in preventing fouling. The feed-forward loop which had never before operated was now providing the necessary control information, without the need for multi-staged 'tweaking.' With implementation of the new coalescer solution the losses due to poor blending were eliminated. The cost of each high efficiency liquid / liquid coalescer sample conditioning system was less than 5,000 US dollars and resulted in an estimated payback period of one week.

Case History - Canadian Refinery

Background / Problem

At a Canadian Refinery, the presence of amine and heavy hydrocarbons in the fuel gas sampling system caused fouling of the on-line fuel gas density and gas chromatographic analyzers. The fast loop flow rate was 100 scfm at an operating pressure of 3.8 barg (55 psig) and operating temperature of 176°C (80°F). Previously, the sample was passed through a nominally rated pre-filter followed by a conventional liquid / gas coalescer. Due to poor protection and amine ingress, the analyzers were not operable.

Solution

The refinery decided to protect four streams, using high efficiency liquid / gas coalescers. Each system contained a single liquid / gas coalescer constructed of glass fiber media that

was specially surface treated to prevent wetting. The coalescer was 254 mm (10 inch) long by 70 mm (2.75 inch) diameter. The coalescer had a maximum rated flow of 200 scfm. The coalescer housing was made of carbon steel with a pressure rating of 20.7 barg (300 psig).

After one year with the high efficiency liquid / gas coalescer installation, the refiner experienced no further problems with analyzer fouling. Furthermore, the protection provided by the coalescer allowed for on-line control of the amine contactor permitting improved gas quality, and reduced amine losses. The cost of each of the high efficiency coalescer sample conditioning systems was less than 5,000 US dollars and resulted in an estimated payback period of a few weeks.

Conclusions

The application of high efficiency coalescer technology to analyzer protection has been proven to be a cost effective means of ensuring analyzer reliability. Advanced coalescer materials allow for the separation of aerosols from gases and the separation of difficult emulsions that could not be accomplished with previous technologies. The use of the fast loop

configuration with small scale coalescers has resulted in very simple separation systems that don't require level controls or automated discharge valves. Case histories from a Canadian and European refinery showed that these analyzer protection systems are relatively inexpensive and have very short pay back periods.

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