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*AGAR probes installed on a desalter in the AMOCO Mandan Refinery*

## Minimize Wastewater Contamination

Source reduction techniques dramatically reduce hydrocarbons lost to sewer system

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**A**veraged total hydrocarbon releases to refinery sewers range from 0.5% to 4.0% of the total crude charge. Unfortunately, refiners are losing valuable feedstocks to the sewer and must spend nearly \$10/bbl to recover and reprocess lost hydrocarbons.

The desalting system is the largest contributor to wastewater; improving operating methods on this unit can reduce shutdowns and maintenance expenses. Equally important, better operating practices can decrease organic loading on the wastewater treating unit. Several case histories illustrate various source reduction methods to minimize hydrocarbon emulsion losses to sewer.

**Reduce losses at the source.** Due to a mature and more competitive marketplace, operating companies are re-evaluating fundamental manufacturing strategies. Consequently, the incentive to apply new technologies and improve operations is more compelling than ever before. New measurement technologies, such as energy absorption, have steadily entered the marketplace to meet this need.

Source reduction is an area where innovative technology is being evaluated and used by many major oil and petrochemical companies. The most effective way of reducing the hydrocarbon content in final effluent is to avoid contaminant losses at their source. Energy absorption (EA) technology has proven to be a useful tool when controlling the amount of hydrocarbons sent to wastewater treatment plants (WWTPs). EA can be applied for monitoring and controlling many separation processes. Additionally, these new control systems help to relieve the pressure from tighter environmental restrictions by reducing the quantity of hydrocarbons released to wastewater pretreatment systems.

Field applications have verified that EA technology enables operators to meet operational goals cost-



**Fig. 1.** Energy absorption probes system installed on an electrostatic dehydrator (desalter) for interface control.

effectively. Many operating companies worldwide are documenting significant savings through equipment availability, minimized wastewater treatment, lower recovery/reprocessing costs, while still achieving compliance with environmental legislation (such as the U.S. Benzene NESHAPS).

**Incentives for improved control.** The traditional approach to minimize wastewater contamination does not focus on solving the problem at the source. Instead, wastewater streams are combined into a common system, which is then processed through slop tanks, CPI's, API's, hydrocyclones, air flotation units and/or benzene strippers. Although, these processes eventually remove hydrocarbons from the wastewater to required levels, treatment costs can be particularly high.

These costs include: specialty chemicals needed to break emulsions at the WWTP and the expense to reprocess recovered hydrocarbons. Many refiners operating their crude units near maximum capacities will suffer significant lost opportunity costs as fresh crude feed is displaced to process recovered oil. This can further exacerbate already poor industry margins.

Typical costs have been documented in an independent study by Wright Killen/Ernst & Young. The consultants surveyed a representative portion of U.S. Gulf Coast refining industry to determine typical industry oily-water treating requirements, crude and product losses, and associated costs.

Study data show that total hydrocarbon releases to plant sewers from all refinery sources normally ranged from 0.5% to 4.0% of total crude charge. Addi-

tionally, for an average U.S. Gulf Coast refinery, total costs for recovering and reprocessing these releases is \$9.64/bbl. Therefore, if the refinery throughput is 100,000 bpd and it is releasing only 1% of this to the sewers, the recovery and reprocessing costs to the refinery are approximately \$10,000/day.

**Improved approach: controlling the source.** Instead of treating the wastewater after it has been contaminated, it is more efficient to identify the stream and use more sophisticated control to prevent contamination at the source. In a typical crude oil refinery, contamination contributors to wastewater (expressed as a percentage of total oil requiring recovery) can be quantified:

- Desalters 40%
- Storage tanks 20%
- Slop oil recovery 15%
- Other processes 25%.

If improved control methods can be applied to these processes (minimizing hydrocarbons released into the wastewater), then significant operating credits could be realized.

**Optimizing the process.** An efficient process is the most profitable. A good example of such a system is the crude oil desalting process. Improved control of this unit can facilitate impressive returns such as: longer run times, lower equipment fouling and corrosion, and reduced maintenance requirements between and during shutdowns. The desalting system is a particularly good example to demonstrate source reduction opportunities. The desalter not only has a critical impact on operating costs, but also on the wastewater treatment. The effects on waste treatment facilities from poor desalter performance become increasingly important as emissions limits are more stringently enforced by government legislation.

Many refiners try optimizing the desalter via chemical addition. These chemicals not only have a direct price, but their potential effects on downstream process equipment and some catalysts must be considered. But even under the best circumstances, chemical alternatives should be used only after more efficient control alternatives have been explored.

**Separation processes.** When a specific separation process is identified for source reduction, the process media's characteristics must be considered. Then the best ways of controlling separation must be determined. The interface between hydrocarbon and aqueous phases is rarely clear cut, especially in desalters. Historically, level-control instruments such as sight glasses, floats, displacers, differential pressure sensors and capacitance probes have been used to control interface. Results obtained from these technologies have ranged from acceptable (under ideal operating conditions) to very poor and misleading (during upset conditions). This is not necessarily due to any failure of the specific level control instruments, rather it reflects a failure to confirm that a true level is present.

When using specific gravity-dependent control for a separation, phase densities must be specified from product data and possible variations of these densities are not always addressed. However, densities vary,

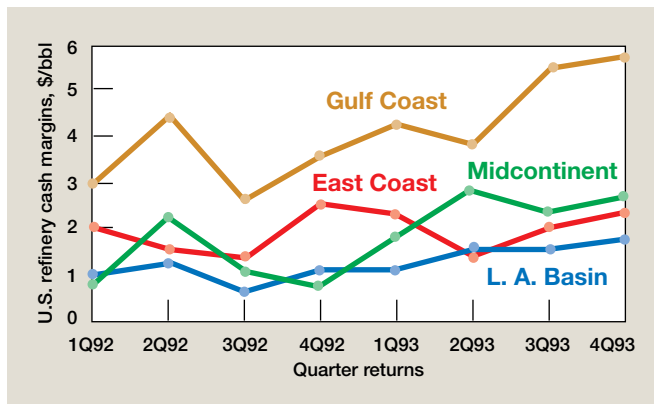


Fig. 2. Refinery cash margins by U.S. locations.

especially during startup, shutdown and system upsets when accurate readings are most critical. Operator reliance on the accuracy from resultant level readings has often led to problems. Externally-mounted instruments, such as sight glasses, are equally ineffective because conditions outside of the vessel are rarely representative of those within. Of the level-dependent instruments used on separators, capacitance probes have performed favorably. However, their effectiveness is limited by conductivity variations, "blindness" from coatings and their inability to detect suspended oil in water.

**Other solutions.** EA technology is more sophisticated than level control instrumentation and has been effectively used on source-reduction efforts. These instruments satisfy several basic requirements critical for reduction applications:

- ▶ Direct contact with the process (inserted into the system)
- ▶ Quantitative measurement capability of 0% to 100% hydrocarbon/water concentration (in both oil-continuous and water-continuous phases)
- ▶ Local or point specific measurement (avoids errors due to averaging over a large hydrocarbon/water distribution)
- ▶ Minimal affect on measurement from fluid properties (specific gravity, pressure, temperature, viscosity and coating build-ups).

The EA probes use a transmitter/antenna combination intrusive to the process. Instruments are positioned to penetrate the tank or vessel so that their antennae reside at the specific points where measurement is desired. It uses a high frequency electromagnetic measurement to determine volume percentages in two-phase mixtures. The signal from each instrument is expressed in units of volume percent of the phases (typically oil and water) and reflects the fluid content in the immediate vicinity. The system monitors the position of an interface, but also can track changes in the size and rate of growth of an emulsion or dispersion. They can identify the hydrocarbon dispersion in the aqueous phase that occurs at and below the bottom of an emulsion layer. When used in separators, EA monitors the percentages of water at various points or levels within the system, either controlling or monitoring the quality of the separation as a function of the relative content of the phases.

Most important to the operator is that by using EA



technology, they have eyes into the process. They can identify and overcome problems normally associated with separation operations. This *insight* allows operators to anticipate and respond to potential upsets, receive advanced warning of an upset and optimize the system to correct and avoid such upsets.

Reducing oil loss to the wastewater treatment systems lessens slop oil recovery demand and minimizes the pollutant content of the final effluent. Applying source-reduction techniques help plants meet their local discharge regulations, while reducing recovery work required.

## CASE STUDIES

Amoco's Mandan refinery needed to reduce its total plant benzene discharge below 10 metric tons/year (mtpy). This decreased level would allow the refinery to be reclassified under existing environmental legislation. Using the traditional approach of re-designing and expanding the WWTP to reduce benzene levels, costs were estimated to exceed \$70 million. However, combining source reduction with several other water reuse initiatives, the refinery's total capital investment was less than \$4 million. The source reduction efforts subsequently reduced annual benzene discharge from an original level of 17 mtpy to only 3 mtpy (an 80% reduction). This reduction not only exceeded required compliance with EPA regulations, but dramatically reduced emission levels, thus enabling the refinery to be reclassified.

**Tank farm.** Amoco's difficulties in dewatering floating-roof tanks with minimal hydrocarbon losses had been quite complicated, especially during rainy weather. The refinery's engineers selected EA for this task after testing several other technologies. The alternative methods were found to be very limited, unreliable and difficult to operate even in good weather conditions.

One method previously used by Amoco involved a floating device with a swing arm (requiring manual adjustment) for sample collection. Mandan found this approach to be cumbersome and not particularly accurate. In addition, because the task was labor-intensive, the sampling frequency was not sufficient to deliver the required information in a timely manner. Replacing the older method with EA, provided continuous operation and required comparatively little operator involvement.

**The desalters.** In the more demanding environment of the desalters, Amoco had developed a procedure of purging the emulsion layer from the vessel during severe upset periods. Operations staff prided themselves on performing this function; they developed the determination and execution of purging to an *art*. Using EA methods for this application, however, converted this *art* into a *science*. The EA probes were preset to continuously indicate the percentage of water in the emulsion layer and then automatically determine the optimum time to purge.

**Engineering design, construction and startup.** Installing the probes in the desalters was quite simple, but more significantly did not require any downtime (Fig. 1). The probe entries were hot-tapped onto the vessel at normal operating conditions. The hot tapping was done through a vertical manway, with a specifically

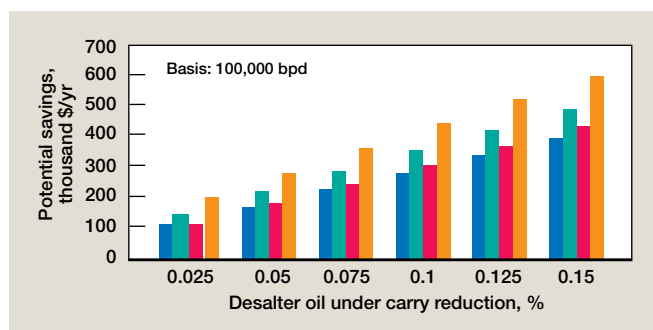


Fig. 3. Potential savings due to reducing hydrocarbon losses in the desalting process.

designed and sized segmented probe so that the segments (each several feet in length) could be sequentially installed in an area with very limited ground clearance. Three years later during a scheduled turnaround, the primary control probes were removed and replaced with single-piece probes. The segmented probe had operated flawlessly, however, the new single-piece probe was installed for improved convenience and to avoid using a multi-segment probe (with larger cross-sectional area) in a high-pressure vessel.

**Run length, debugging, optimization and process control.** The Mandan refinery's primary objectives were: enhanced run length and improved process control and unit optimization. Run lengths improved dramatically; the probes proved to be impervious to varying operating conditions and fouling that affected the reliability and operability. The EA systems have been operating in the tank farm since 1991 and in the desalters since 1992, both without any interruption for cleaning or other maintenance.

As with any new technology, training and familiarization is needed. The EA system was a learning experience for the Amoco operators. At the tank farm, the optimum location for the probes on each tank type (crude or finished product) was determined after a few months of field experience. On the desalters, the probes made their measurements within the desalter; thus, operators were using this new instrumentation without being able to physically see the measurement points. Verification was required to instill confidence in the readings; new sampling techniques and a procedure were developed that also followed a learning curve.

**Environmental and operational benefits.** The Mandan refinery substantially reduced hydrocarbons lost to the wastewater system. Equally important, the refinery minimized final effluent benzene by over 80%. The EA system has proven to be very accurate and easy to use. Because the new technology operates on a continual basis, the total effectiveness of the refinery's operation has improved. The probes have enhanced Amoco's sampling techniques, with most of the sampling no longer lost to the sewer.

**Improved manpower utilization.** Amoco has noted multiple benefits in the tank farm water drainage operations. When operators are draining water from a tank, they simply set the probe to close the drain valve when it detects hydrocarbon approaching the drain line. The operator can leave the area to complete other tasks with confidence, since the probe can be adjusted to automatically shutdown at the desired hydrocarbon

concentration. The system has also been set-up to activate a control room alarm and/or local signal to let the operator know the operation is complete. Besides adding flexibility and efficiency to the operator work force, the potential for either under- or over-draining the tanks has been virtually eliminated.

**Better control.** Other refiners who have retrofitted their desalters with EA technology have observed a dramatic shift in operator understanding of desalter operations. Before using EA methods, desalter upsets often remained undetected until they manifested themselves in downstream equipment disruptions. In Amoco's 75,000-bpd refinery, crude cuts of 10,000 bpd to 15,000 bpd were not uncommon during severe desalter upsets. Following installation of the improved control system, operators reported a greatly enhanced sense of control over the unit from the monitoring methods that allowed them to see and respond to potential upsets in a systematic and effective fashion. While desalter operations and tank-water drawing represent about 75% of the source reduction opportunities in a refinery, similar environmental, profitability and operational benefits are possible by applying EA technology in any refinery process that involves controlling hydrocarbon/water separation.

**Case history two—the Reichstett-Vendenheim Refinery, France.** The selection process for new interface control instrumentation was part of a desalter system redesign for Shell-advised refineries. The inadequacy of existing density-based instruments had been confirmed by failure reports from many sites. During this process, Shell determined that sharp interfaces required by traditional level instrumentation were not realistic. The problems were aggravated when the displacers were mounted in external chambers. Shell's multidisciplinary group of specialists decided to evaluate EA, with controlling percentage oil-in-water as the focus objective.

**Technology choice.** Shell's instrument engineers initially reacted by simply comparing the cost of EA probes with other density-based units. However, the company's process engineers provided data and references from exploration and production operations. This practical experience documented successful application of the new technology. The decision-making team began evaluating all alternatives according to pre-established criteria, among them oil-in-water detection. Capacitance technology also had some track record in the field and has not improved performance of these systems. Even lesser-known technologies such as time domain reflectometry (TDR) were reviewed, but were found to be unsuitable for process conditions. The team concluded that none of the available level measurement instruments would accomplish the objectives. Consequently, the EA oil-water measurement instruments were selected for testing to confirm performance figures and reliability in demanding conditions.

**Engineering design, construction.** Because the standards are not yet equal on all continents, the design of EA probes was adapted to conform to Shell's flanged connection requirements for the Reichstett refinery. (For example, most refineries later opted for placing sample valves on the connections to enable them to

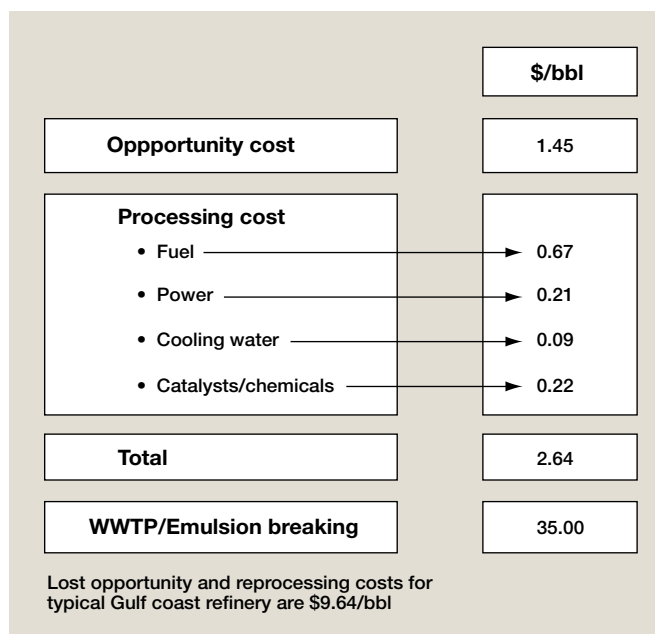


Fig. 4. Reprocessing costs for a typical U.S. Gulf Coast refinery.

monitor the function and output of the probes.) The most critical factor for Shell was acceptance of the new instrumentation. Reliance on accuracy was emphasized and periodic sampling for verification was encouraged.

**Debugging, optimization and process control.** The first installed probes were closely followed to evaluate performance. The immediate success of the control applications, however, nearly rendered proper evaluation impossible. Operations managers did not allow the probes to be touched for recalibration or settings alterations. The probes were regarded as (and remain perceived as) "pieces of magic fit for the job." Because they required no maintenance, instrument engineers did not have the opportunity to become familiar with them. Therefore, it was advised that the engineers be allowed to experiment with probes destined for new installations in workshop configurations so they could become familiar with the probe behavior before installation.

**Improved control.** The reliability of the resultant interface control greatly contributed to the total success of the re-design project. Savings in chemical consumption and reduced oil in the effluent water streams readily justified selecting the new technology. Reduced overhead corrosion and prolonged catalyst life also represented substantial savings, but required greater study to quantify. More important to Shell, however, was the contribution of the new control systems to improvements in plant availability, unit throughput, equipment reliability and total quality of control.

The EA instruments have since been selected as essential and standard elements for all future re-design projects. For example, the Shell Pernis Refinery (Netherlands) became one of the many group-advised refineries to follow the Reichstett lead, and it has reported very positive results.

**Economic benefits.** A Hawaiian refinery has used EA technology to reduce their desalting process chemical feed by an average of 25% to 33% (resulting in a

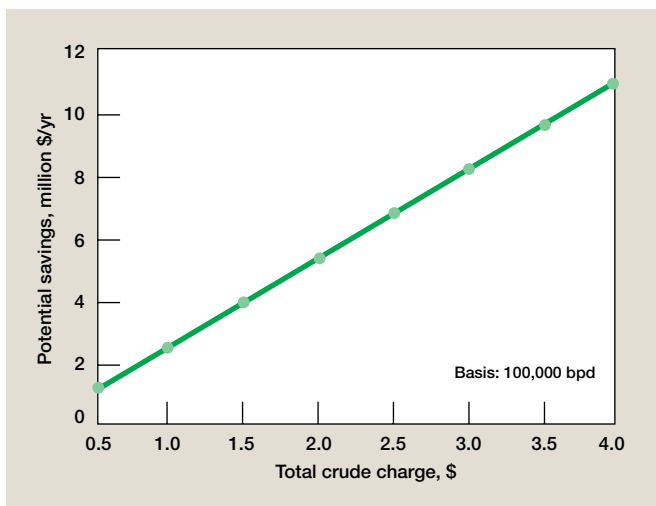


Fig. 5. Plant-wide savings by reducing hydrocarbon losses to sewer.

calculated payback of 2.5 months). Another refinery in Baton Rouge reported that the payback for its desalter control investment took approximately six months. A Louisiana refinery experienced more than an 80% reduction in effluent brine oil-in-water content (with an annualized savings of \$200,000). In South Texas, a refinery reduced their desalter brine oil content (previously ranging from 0.5% to 1.0%) to a level consistently less than 500 ppm. A Southern California refinery using EA techniques since 1987 reduced their demulsifying chemical consumption by more than 30%, while still minimizing effluent oil-in-water content. Finally, a Mississippi refiner has reduced crude oil in its desalter brine effluent to less than 0.5% from a previous level of 2% to 4%. In each case, the benefits to the plant reached beyond a simple improvement in effluent condition. Reduction in slop-oil recovery and reprocessing costs significantly improved facility bottom-line operating costs as well.

**Profitability improvement.** From the study by Wright Killen/Ernst & Young, improvement in profitability can be realized by applying source reduction technology. The data and conclusions are based on interviews with representative refineries in the U.S. currently using EA technology. This data was compared with overall industry margins and operational data (Fig. 2), and final conclusions were extrapolated.

The data indicated that conventional single-stage desalter design and operations typically limit control of oil undercarry in the washwater effluent to no less than 0.5% to 1.0%. For some refiners, oil undercarry runs as high as 3.5% to 4.0%. Expressed in terms of total crude charge to the refinery, oil undercarry losses from desalters range from 0.025% to 0.15% of feed to the crude units. Fig. 3 illustrates the potential savings specific to reduction of losses in the desalting process.

As much as 20% of the oil dropped to the sewer will reach the WWTU. At this point, the remaining oil is in emulsion—making it difficult and costly to recover. Average recovery costs were reported to be \$7.00/bbl of emulsion with a 20% oil concentration, or \$35.00/bbl of recovered oil.

**Chemical-injection program costs.** Also, found in

the same study is that refiners using the EA methods to monitor desalter emulsion characteristics better controlled their chemical injection programs. The potential savings from reducing lost opportunity costs, emulsion handling costs, and desalter chemical costs for an average U.S. Gulf Coast refinery, is \$183,000/yr. (This conclusion is based on the conservative assumption of an oil undercarry reduction efficiency of 80%.) Per barrel costs are detailed in Fig. 4.

As the lost opportunity and reprocessing costs for a U.S. Gulf Coast refiner are \$9.64/bbl, achieving an 80% reduction in hydrocarbon losses to the sewer from all sources equal to only 0.5% of the total crude can yield potential savings of \$1.4 million/yr. Fig. 5 shows how the plant-wide savings can increase with higher loss rates.

Eliminating pollutants at the generating source allows the facility to meet legislated removal requirements without large capital outlays for downstream treating equipment. This approach also reduces the operating costs of existing wastewater handling facilities.

Refiners and other petrochemical industry operators feel the pressure of restricted effluent contamination legislation. Source reduction is an attractive alternative to costly treatment plant extensions and upgrades. Improved interface control can deliver high return on investment through the additional positive impact on throughput and equipment availability and reliability.

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