POLAREX®
EXTRACTIVE SEPARATION TECHNOLOGY

The POLAREX® technology represents a compact, modular approach to the separation of dissolved contaminants. Historically, washing or scrubbing made use of large water wash / coalescers or large contactor towers to achieve reasonable performance. The POLAREX® technology allows high efficiency contact, extraction and separation at a fraction of the cost and at a fraction of the footprint of conventional approaches; reducing project capital by up to 80% and providing a solution that makes both dollars and sense.

AS LITTLE AS 20% OF THE CAPITAL THAN CONVENTIONAL SYSTEMS

Polarex® provides gas processors, chemical manufacturers, and refiners dramatically improved separation of entrained and dissolved contaminants relative to that achievable through implementation of conventional water wash or solvent scrubbing towers. Conventional approaches to washing or scrubbing are often limited by contact efficiency and subsequent separation efficiency, resulting in limited performance and large capital investments. The platform was developed utilizing our advanced micro and nano-fiber technology to create a single stage, high efficiency, structured contactor / separator.

The patented Polarex® technology may be applied to the extraction of soluble components from either liquid or gas process streams. It has application to both contaminant removal (e.g. - caustic, dissolved acids, salts, acid gases or reaction by-products) as well as recovery of valuable products or solvents (e.g. – recover soluble amines from treated LPG) for as little as 20% of the capital associated with a conventional wash system.

Applied to batch chemical processes, Polarex® increases process speed and operational flexibility. Traditional approaches to neutralization or product washing require a lengthy neutralization or wash step followed by decanting and transfer. Not only do these steps slow reactor turn over, they also frequently result in carry over of salts and impurities due to the limited separation effectiveness of decanting, particularly with emulsified product / water mixtures. It allows neutralization or washing to proceed on-line during product transfer, allowing the wash / decant steps to be eliminated entirely.

POLAREX®
EXTRACTIVE SEPARATION TECHNOLOGY

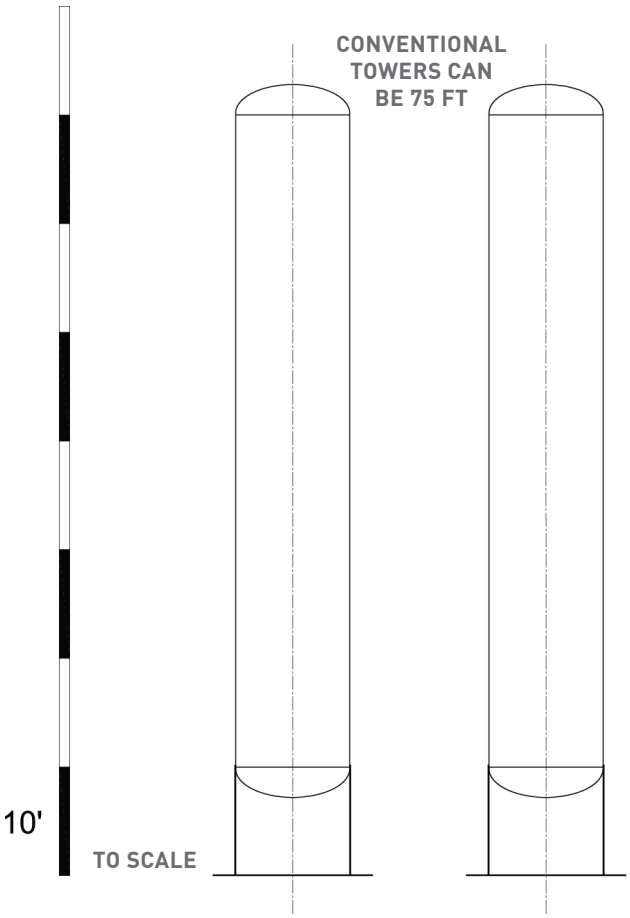
Application of the POLAREX® technology to the recovery of amine from treated LPG enabled a refiner to reduce amine losses from 276 ppm to approximately 10 ppm in the treated LPG, allowing recovery of over $300,000 in amine annually. Reduction in the amount of amine leaving the contactor also resolved the persistent operational challenges in the downstream caustic treater. The POLAREX® solution was provided at 70% lower installed capital relative to the conventional water wash / coalescer alternative, providing immediate returns.

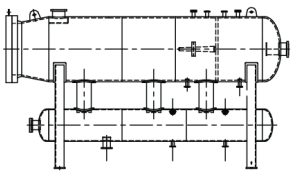
APPLICATION FLEXIBILITY

Pentair's POLAREX® technology may be applied to both gas and liquid process streams. It has been installed on liquid process streams from 20 gpm to over 2,900 gpm and with liquid viscosities as great as several thousand centipoise. The robust design affords reliable performance in a scalable, modular package appropriate for both new capital projects as well as placement in existing plant environments. Each system is designed to address the specific operational constraints of the facility and process.

The flexibility of the technology has allowed its application as a replacement for amine contacting towers in the processing of natural gas liquids, the replacement of a caustic scrubbing tower in an LPG treating unit, removal of chlorides from reformer off gas streams and the neutralization of an acidic catalyst in the manufacture of silicone fluids. The impact of POLAREX® is large, from both a capital standpoint and with regard to reducing ongoing plant operating expense.

The compact footprint results in significantly lower installed costs. As an example, a POLAREX® system employed in a refinery LPG treating unit made use of a 36" O.D. x 8' long POLAREX® vessel in lieu of a caustic scrubbing tower of 8' diameter and 40' height. The modular nature of allowed the system to be installed within the existing available footprint of the unit, while the alternative scrubbing tower would have required the additional cost of demolition of out-of-service process equipment.





PENTAIR

SEPARATION SYSTEMS

EXTRACTIVE SEPARATIONS FOR POLAR COMPOUNDS FROM HYDROCARBONS

Hydrocarbon Streams are contaminated by soluble polar (or ionic) contamination in a variety of ways (viz., caustic treatment, amine treatment, acid catalysts etc). The contaminant typically exists within the hydrocarbon phase in a soluble form, and in some cases it may not even be ionized within the non-polar hydrocarbon. Nevertheless, it is generally necessary to remove these contaminants. In some cases, the contaminants may poison downstream process equipment; or example, diesel fired turbines are sensitive to alkali metal contaminants; selective hydrogenation units (SHU) are sensitive to sodium). In other cases, these soluble contaminants represent an ongoing operating cost (i.e., amine dissolved in a C3/C4 stream needs to be made up with fresh (expensive) amine).

Conventional Approaches to removing the dissolved polar components, utilize washing the hydrocarbon with water. Typical approaches involve:

- Water-Wash Towers
- Water Injection followed by Coalescer or Knock-Out

In all cases, the process involves dispersing the water into the hydrocarbon stream followed by a separation downstream. Since the mixing and the separation are not very efficient, typical water-washes utilize large quantities of water (20 – 40%) that are run in a re-circulating loop. A small fraction of water is continually added, and a small fraction of water is purged. A typical tray, or packed-column, offers 60% stage-wise efficiency for mass-transfer and consequently requires a large wash column for mass transfer. Additionally, multiple stages may need to be applied to overcome the low stage-wise efficiencies. Finally, these systems do not have high aqueous-hydrocarbon separation efficiencies; thereby, increasing the likelihood of the extracted component being ***re-entrained*** back into the hydrocarbon.

Efficient Extraction

Efficient extraction requires a very high specific surface area for contact between the two fluid phases to allow the dissolved component to transfer into the extracting phase. Typically, the specific surface area (wetted surface area per unit volume) of a trayed or packed column is such that a single stage offers approximately 60% or lower efficiency of mass transfer, on the basis of an equilibrium stage. If water is injected into the stream followed by a staticmixer, the degree of mass transfer efficiency is related to the droplet distribution produced across the static mixer, or spray nozzle. The trade-off typically faced is related to the separation efficiency of the downstream separator. The smaller the droplets generated by the mixing device, the harder the downstream separation becomes. The effect of droplet size on specific surface area, and on residence time needed for separation is illustrated in **Table 1**.

Table 1: Estimated Specific Surface Area and Separation Requirements

Droplet Size (micron)	Specific Surface Area (m2/m3)	Residence Time For Separation
500	600	3 min
250	1200	10 min
100	3000	~1 hour
10	30,000	~5 days
1	300,000	~1 year

System consists of 5% water in a hydrocarbon stream with a specific gravity of 0.4 g/cm3 and a viscosity of 1 cP.

Figure 1: Polarex™ Skid for acid removal from a non-polar fluid

As can be seen, the smaller the droplets, the higher the specific surface area, but since the separation requires exponentially higher residence time, there is a practical limit to this approach.

This practical limit implies that small droplets are not sought to be created, and therefore high specific surface areas are not obtained, and consequently high stage-wise efficiencies not observed. The conventional means of addressing these limitations is to either increase the number of stages, which means building a taller extraction column, and increasing the extractant flow rate, which requires larger separation sections.

Micro-structured Extraction seeks to address the inherent limitations of conventional separation systems by facilitating a high specific surface area contact between the two phases, without necessarily requiring sub-micron droplet formation. The mass transfer occurs on the micro-structured extraction media. This level of contact is then immediately followed by an effective means of capturing the dispersed phase and effectively separating it out of the system by the creation of large droplets, through the use of Pentair's **APEX®** element technology within a Polarex® system. The high specific contact area may be an order of magnitude, or more, larger than that possible in conventional extraction systems, which allows for exceptionally high stage-wise efficiencies. **APEX®** is specifically intended to allow large flows to be handled in a smaller vessel, implying lower capital costs.

Capital Costs are a major factor affecting the decision making with regard to the installation of any separation technology and are directly related to the size of the pressure vessels required for a particular flow rate. An example of the implications of the capital cost tradeoff is illustrated in Table 2. As can be seen from Table 2, the conventional approach requires large vessels, recirculating pumps, large foundations and therefore very high capital costs. Table 2 shows that Polarex® vessels are small, and as Figure 1 indicates Polarex® may also be skidded.

Table 2: Amine recovery from a 8000 bpd C3/C4 stream

	Conventional	POLAREX®
Water Injection	2%	2%
Water Recirculation	25%	-
Pump Capacity	100 gpm	-
Coalescer Size	5 ft (OD) x 20 ft (L)	-
Polarex Vessel	-	2 ft (OD) x 8 ft (L)

ABOUT POLAREX®

Polarex® US Patent 8425663, an extractive separations technology provides gas processors, chemical manufacturers, and refiners dramatically improved separation of entrained and dissolved contaminants. It is designed to replace conventional water wash and solvent scrubbing towers.

The patented Polarex® technology may be applied to the extraction of soluble components from either liquid or gas process streams. It has application to both contaminant removal (e.g. - caustic, dissolved acids, salts, acid gases or reaction by-products) as well as recovery of valuable products or solvents (e.g. – recover soluble amines from treated LPG or recovery of LPG from high BTU natural gas streams) for as little as 20% of the capital associated with a conventional system. It has already been successfully installed in several NGL treating applications (displacing conventional amine contactors) with staggering results of 86% of operational time above nameplate capacity and 19% above design while maintaining treating efficiency.