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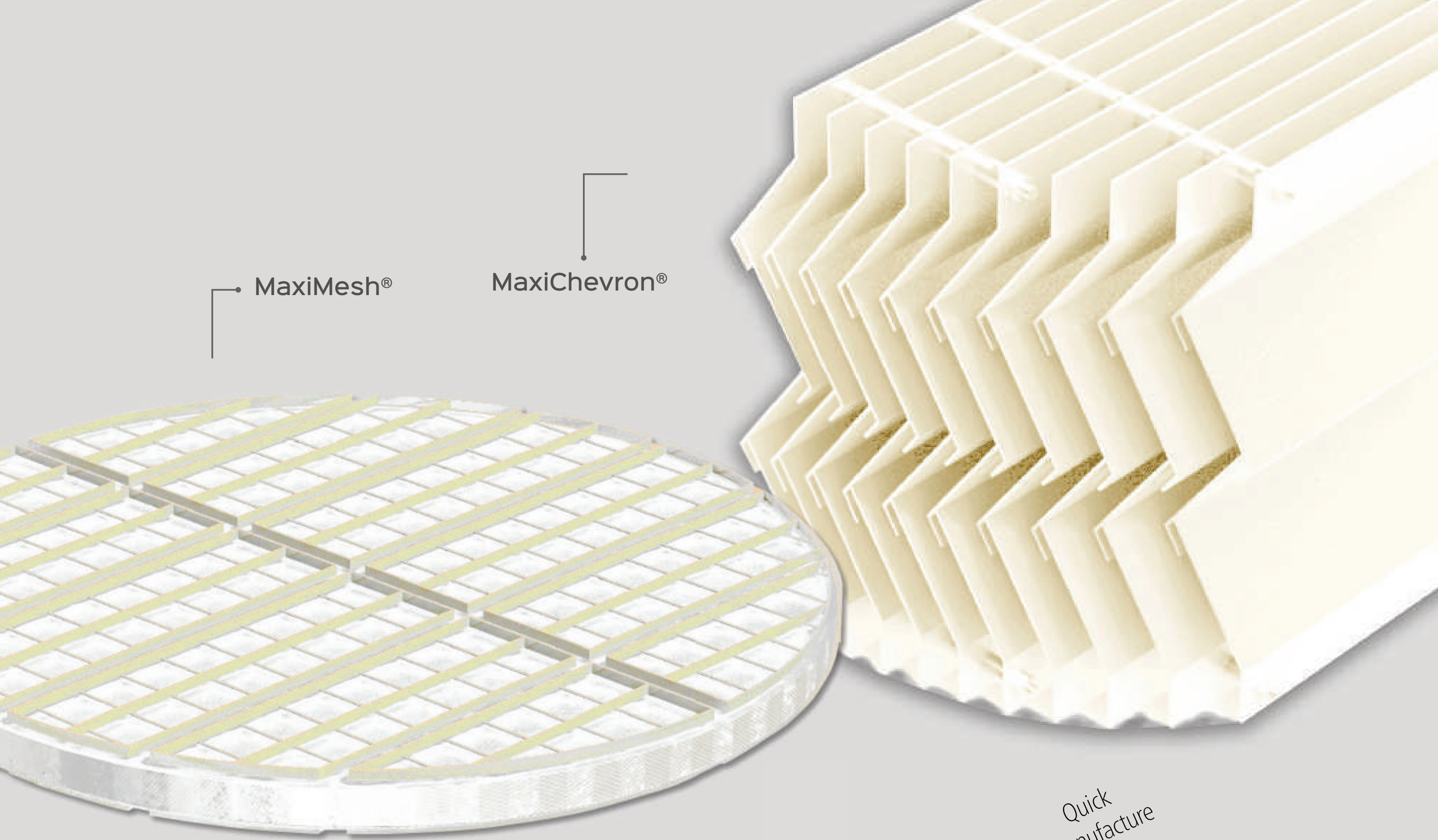
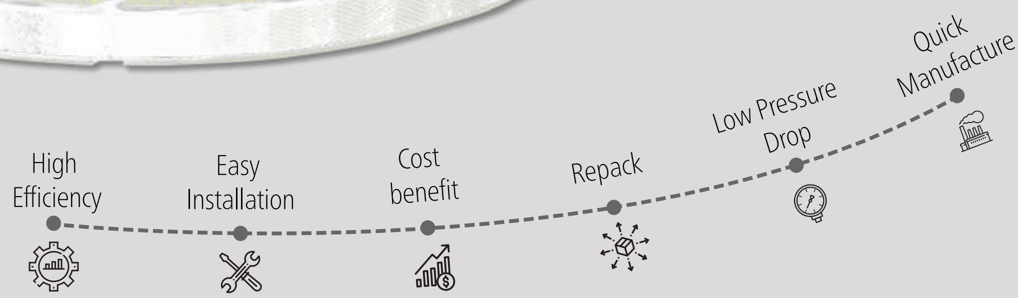
Mist Eliminators





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Effective

Mist Elimination

Why choose Clark Solutions for your mist elimination needs? Inefficient or improper mist elimination may result in serios equipment damage, product loss or environmental pollution. Sometimes, small details make huge differences in mist elimination performance. Clark Solutions has been a leader in mist elimination research, design and innovation for more the last quarter century. Our mist eliminators will outperform traditional equipment improving product recovery, extending production cycles and minimizing environmental impact. If you look for innovative solutions and choose quality over ordinary performance, Clark Solutions is your next stop.

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Mist Eliminators Continuous Spray Washing for Heavy Fouling Processes

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1. Introduction

In phosphoric acid plants, mist eliminators downstream from evaporators can affect capacity and uptime if not properly designed.

Vane-type mist eliminators are usually chosen for this process. This type of low pressure drop mist eliminator consists of spaced blades offering an undulatory stream pathway. The alternating path direction promotes droplet inertial impaction, a collection mechanism where density and viscosity differences between vapor and liquid causes droplet disengagement as the latter higher inertia makes it unable for a set of droplets to rapidly respond to abrupt changes in trajectory. Therefore, entrained liquid collides against mist eliminator walls and are collected and drained.

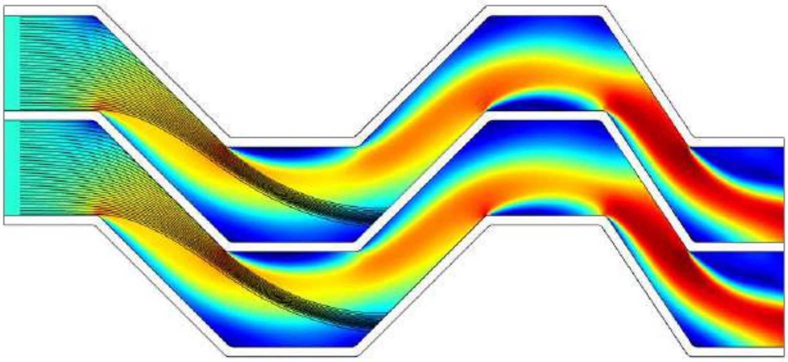

Figure 1: Inertial Impaction in MaxiChevron® Model 3.11.30

Many processes operate with saturated solutions which will precipitate solids due to pressure and thermal effects. Wide spacing and good capability for solid handling does not mean mist eliminators are immune to fouling. For this reason, a properly designed spray washing system for fouling processes such as phosphoric acid mist elimination was developed by Clark Solutions.

2. Precipitation and Fouling

Solids carried by vapor stream are basically calcium sulfate ($CaSO_4$), result of the first stages in the plant, in which phosphate rock is attacked by sulfuric acid. Some of the $CaSO_4$ bypass the filters and get to mist eliminators. This solid has a high fouling aspect and is difficult to remove, since it forms plaster.

$$Ca_3(PO_4)_2 + 3\ H_2SO_4 \rightarrow 2\ H_3PO_4 + 3\ CaSO_4$$

Calcium sulfate has a solubility around 7 g/L in 30% phosphoric acid (TABER, 1905) which means that this component can be carried in solid as well as diluted form. The amount of entrained solid can be evaluated by empirical or theoretical means:

- Intervals for equipment removal for cleaning
- Estimates of entrained liquid flow and therefore solid content

Table 1: Solubility of calcium sulfate on phosphoric acid (TABER, 1905).

Grams P_2O_5 per Liter	Grams $CaSO_4$ per Liter	Density of Solutions 25°/25°
0.0	2.126	-
5.0	3.138	1.002
10.5	3.734	1.007
21.4	4.456	1.016
46.3	5.760	1.035
105.3	7.318	1.075
145.1	7.920	1.106
204.9	8.383	1.145
312.0	7.965	1.221
395.7	6.848	1.230
494.6	5.573	1.344

Fouling can occur by two means:

- Evaporation of saturated droplets collected on vane-type mist eliminator walls due to equipment pressure gradient
- Solids accumulation on blades by direct impact against existing fouling layer

Solids accumulation decreases mist eliminator active cross-sectional area, causing velocity profile changes and pressure drop increase. Pressure drop increase reduces evaporation capacity. Therefore, the mist eliminator is removed for cleaning and installed again – or replaced in extreme cases. Besides downtime, which is costly, cleaning with high pressure water could damage the blades, decreasing equipment lifespan.

3. Solution in keeping the solution

With these issues in mind, Clark Solutions offers the MaxiWash™ concept coupled with MaxiChevron® mist eliminators in a wide range of materials and designs to address process specific restraints. The MaxiWash™ is a spray washing system with the goal of maintaining mist eliminator surfaces continually wet, with a continuous flowing thin liquid film on the blades. The liquid solution used is typically the process solution, such as phosphoric acid.

Figure 2: MaxiChevron® in plastic material

The specially engineered and designed spray nozzles generate droplet size distribution considerably larger than MaxiChevron® collection efficiency, which can collect up to 99,9% in the 10 micron range. Thus, the sprayed liquid will be collected by the mist eliminator.

Two objectives are achieved simultaneously by keeping a continuous liquid film on vane-type walls:

- Evaporation of liquid due to pressure gradient turns irrelevant, since liquid is provided by the sprays at the rate it is evaporated, maintaining solids diluted
- The film prevents free solids to accumulate on walls, carrying down impinged solids alongside liquid draining

A continuous system has benefits over intermittent operation such as:

- Lower water consumption. Intermittent washing requires high pressure and liquid flowrates due to the difficulty of mechanically removing fouled $CaSO_4$, on the other hand, for a continuous washing, the flowrate and pressure can be set as to be minimum, just enough to maintain a thin film and guarantee saturation.
- No clogging. Intermittent washing operates after solid accumulation. Using high pressure intermittent washing could cause blocks of $CaSO_4$ to detach and clog drain pipes. A continuous washing would entirely prevent block formation.
- Solid pre-collection. A continuous washing system maintains a liquid curtain. In the continuous scenario, all carried free solids necessarily passes through a liquid cone formed by the sprays, which helps in solids collection.
- Uptime. Keeping a clean mist eliminator will avoid pressure drop build-up, de-bottlenecking evaporation production.

Continuous washing will collect the solids in a slow and enough pace avoiding its accumulation on walls, substantially increasing maintenance intervals and mist eliminator lifespan.

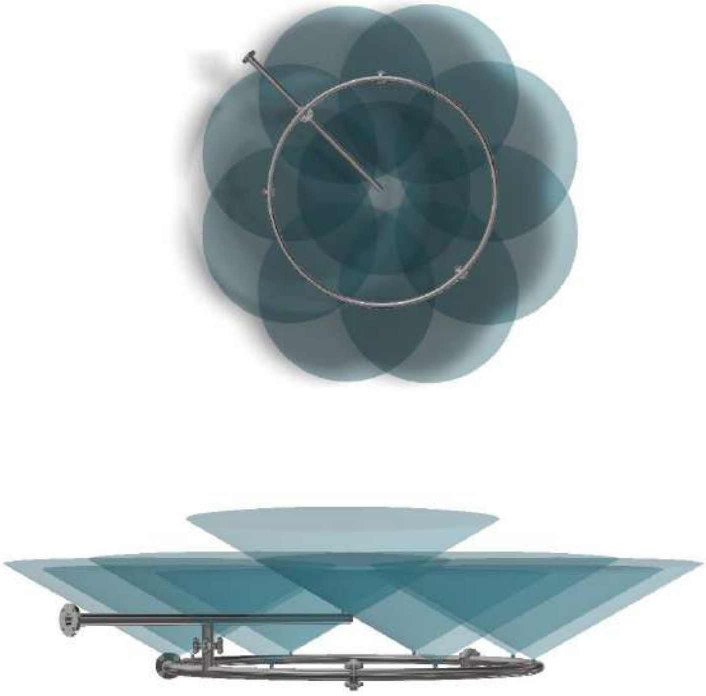

Figure 3: Example of spray arrangement of the MaxiWash™.

4. MaxiWash™ system considerations

As mist elimination is downstream from phosphoric acid evaporators the vapor phase is saturated. The mist eliminator equipment represents a pressure drop, causing a difference in pressure between saturated vapor flow and collected liquid throughout the mist eliminator. This de-entrained solution tends to vaporize and precipitate solids.

Liquid is added to the mist eliminator by continuous spraying to replace solution evaporation and prevent precipitation. Added liquid flow is calculated by comparing mist eliminator pressure drop and system absolute pressure. Estimation of vaporized liquid depends on liquid and vapor compositions, pressure changes and total vapor mass flow along mist eliminator area. Roughly the same amount of vaporized liquid on mist eliminator surface is added in the form of spray solution to keep continuous washing at minimum rate.

Once the spray liquid flowrate is calculated, other aspects must be considered:

- Spray distance to avoid jet deformation
- Pulverization angle (α)
- Number and position of sprays

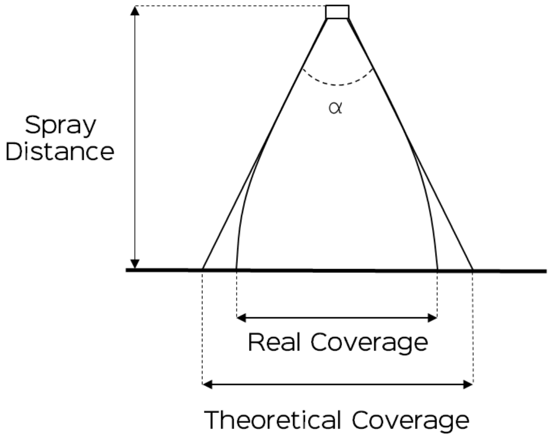

Figure 4: Pulverization angle and spray distance considerations

The number, position and pulverization angle must be adjusted in a way to avoid dead zones, as well as excess superposition.

Table 2: Limitation of the aspects in consideration.

Parameter	Lower Limit	Upper Limit
Number of Sprays	Possibility of Failure	Cost
Pulverization Angle	Dead zones	Excess Superposition Spray against walls
Spray Distance	Too wide pulverization angle requirement	Jet deformation

5. Application

Phosphoric acid mist elimination vessel design sometimes consists of a sequence of mist eliminators, the first stages to collect larger droplets and promote high drainage and the last stages to collect smaller ones as a polishing stage. First stages are typically wider whereas last stages are tighter.

If the MaxiWash™ system is considered in design stage, then the vessel size calculation should consider the cross-sectional area required for MaxiChevron®s and the space for the spray washing setup – mist eliminators placed between 500 to 1,000 mm apart depending on nozzles setup.

Otherwise, in configurations without washing system, normally the mist eliminators are really close to each other and close to inlet and outlet nozzle to get the minimum possible vessel size.

For a system that intends to upgrade with a washing system, Clark Solutions conducts an engineering study to evaluate a MaxiWash™ configuration without the necessity of a new vessel, if possible. Increasing the space between the MaxiChevron® sometimes requires a decrease in cross-sectional area of the mist eliminators – especially for horizontal setups. MaxiChevron®s design is based in Clark Solutions' proprietary methodology, which is accurate enough to refine the design and check if the new area is adequate.

One typical assumption is that vapor velocity at mist eliminator entrance is an average, which means it considers the volumetric flow divided by the cross-sectional area. This information is only true if there is a good enough distribution of the velocity profile at the equipment entrance.

Since it is considerably complex to estimate the behavior of the gas trajectory inside the vessel, Clark Solutions realizes CFD (computational fluid dynamics) studies to analyze this parameter with precision and combine with the calculation methodology for MaxiChevron®'s design.

6. CFD analysis

Study complexity is an important aspect, which means some assumptions must be made. In other words, several geometry details result in more computational time or convergence obstacles. Meaning that simplifications are applied to achieve faster results, however maintaining verisimilitude:

- Screws, hooks and fixation parts are neglected.
- Boundaries do not have thickness

Also, some assumptions regarding the flow:

- The flow is incompressible (global pressure drop is less than 1% of total pressure)
- Isothermal simulation
- Steady state

Once the assumptions are made, the simplified vessel is built in the CFD software and a turbulent flow physics model is applied with the operational conditions to analyze the velocity profile at the entrance surface of the two vane-type mist eliminators.

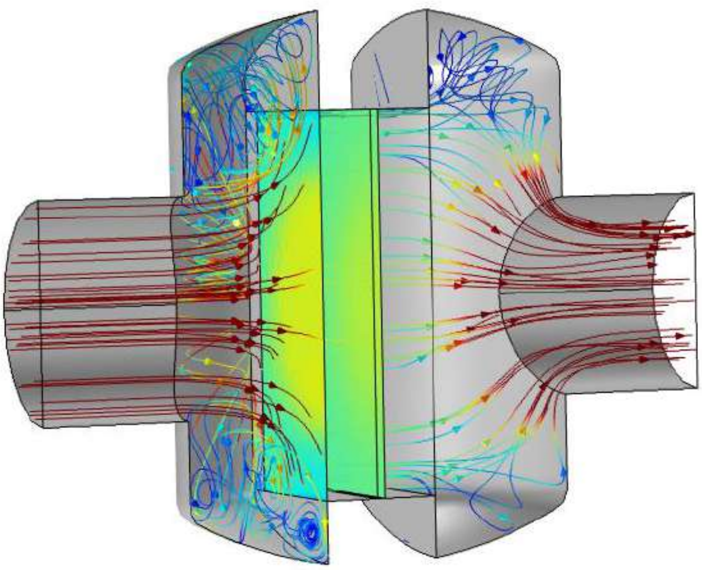

Figure 5: Vane-type mist eliminator without washing system.

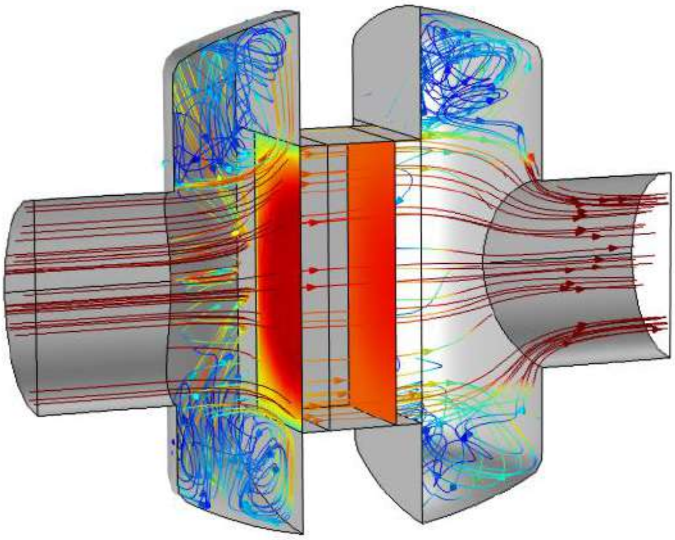

Figure 6: MaxiChevron®s with space for MaxiWash™.

In Figure 5 there is a configuration without space for the washing system (blocks representing vane-type mist eliminators are close to each other) and in Figure 6 with the proper space (blocks are set apart). By the velocity profile color scale (higher velocities in red) it can be observed that the distribution is better at the second vane-type mist eliminator, for both configurations. The velocities in Figure 6 are higher since there is less cross-sectional area, the impact on pressure drop and collection efficiency is analyzed by Clark proprietary methodology.

The colored plot allows a qualitative analysis, a more solid result is accomplished by a quantitative one. The approach is to split the entrance surface area of each MaxiChevron® in regions under different groups of velocities, in other words, the velocity profile is divided in groups of 1 to 2 m/s from the lowest to the highest velocity and it is observed the percentage of the entrance surface area of the mist eliminator with flow at those velocities.

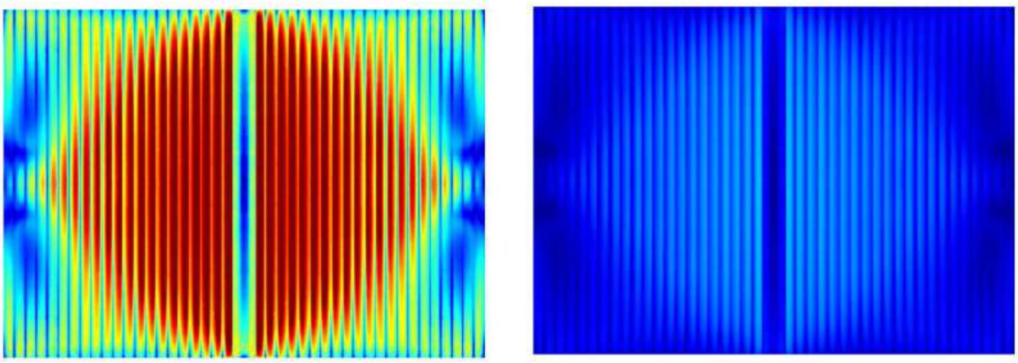

Figure 7: At the left-hand side a bad distribution on mist eliminator entrance, at the right-hand side a good distribution.

A good distribution is represented by a scenario which almost all of the area is in a small range of velocities, what means that there is little variation of velocity over the entrance of the mist eliminator and the assumption of average velocity is accepted.

Table 3: Example of quantitative analysis of velocity profile distribution.

Velocity Groups (m/s)	Cross-Sectional Area Pecentage					
	Vessel Diameter = 2.6 m		Vessel Diameter = 2.8 m		Vessel Diameter = 3.5 m	
	1st Vane	2nd Vane	1st Vane	2nd Vane	1st Vane	2nd Vane
36 to 38	5%	0%	0%	0%	0%	0%
34 to 36	16%	8%	8%	8%	0%	0%
32 to 34	12%	16%	17%	16%	0%	0%
30 to 32	10%	19%	19%	19%	0%	0%
28 to 30	9%	13%	12%	13%	0%	0%
26 to 28	10%	9%	9%	9%	0%	0%
24 to 26	7%	7%	7%	7%	0%	0%
22 to 24	5%	6%	5%	6%	0%	0%
20 to 22	5%	5%	5%	5%	41%	0%
18 to 20	4%	4%	4%	4%	24%	0%
16 to 18	3%	3%	3%	3%	27%	49%
14 to 16	3%	3%	3%	3%	8%	49%
12 to 14	3%	3%	3%	3%	0%	2%
10 to 12	2%	2%	2%	2%	0%	0%
Less than 10	6%	4%	4%	4%	0%	0%

In Table 3, three configurations of vessel diameter are shown. The first two arrangements offer an inadequate distribution in comparison with the third option, in the latter more than 90% of the area is under a very uniform velocity profile, what is considered an adequate distribution.

7. Practical Installations

With more than a decade of experience in continuous washing systems, Clark Solutions has successfully installed MaxiWash™ in many sites in Brazil, obtaining expressive results in decrease of water consumption and maintenance time reduction, for a wide range of industrial branches dealing with mist eliminator fouling, such as phosphoric acid, oil & gas, sugarcane & ethanol and many other industries.

8. Conclusions

MaxiWash™ spray washing system is a concept for processes involving mist elimination with heavy fouling components. The solution is simple and considerably increases equipment uptime and lifespan.

This concept can be applied either for new vessels or already built vessels with fouling issues. For the latter, an engineering study combining Clark design methodology and CFD analysis is realized.

9. References

TABER, W. C. (January de 1905). The Solubility of Calcium Sulphate in Phosphoric Acid Solutions. *J. Phys. Chem*, pp. 626-629.