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# Specifying Internals in Sour Water Strippers – Part 2

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## Abstract

Sour water stripping is a common process in petroleum refineries and other processes where $H_2S$ is present. While not a revenue generator, the sour water treating system is a critical unit operation and can be a significant bottleneck to facility production rates, if it is not adequately sized, or if it is forced to operate at partial loads due to maintenance issues. As a result, a balance must be struck between minimizing capital costs while still providing a reliable and flexible sour water treating system. This article on specifying internals in sour water strippers was originally prepared for the Brimstone Sulfur Recovery Symposium [1]; it has been edited and separated into two parts for publication in Hydrocarbon Processing magazine. Part 1 of this two-part series i) gave an overview of the auxiliary separation equipment needed to remove hydrocarbons and other contaminants from the sour water prior to the stripper and ii) reviewed the design of sour water stripper columns containing trays. This Part 2 reviews the design for packed sour water stripper columns and presents a summary of potential issues that may be encountered in operation of the sour water stripping system.

## 1 Introduction

Sour water stripping is a common unit operation in petroleum refineries and in some larger natural gas treatment facilities. The sour water stripper system receives sour water from different upstream unit operations, which in a petroleum refinery may include crude units, hydrocrackers, hydrotreaters, catalytic crackers, etc. The sour water streams from each of these unit operations will vary in composition but will generally have some fraction of ammonia ($NH_3$) and hydrogen sulfide ($H_2S$) present in solution. This article considers sour water strippers that have $NH_3$ and $H_2S$ as the primary species to be removed; it excludes consideration of other species, such as cyanides, phenol, etc. All recommendations given are in this context.

The sour water stripper system collects the sour water streams from different unit operations, removes hydrocarbons/solids/etc., and removes the $NH_3$ and $H_2S$ from the water by heating and stripping. The liberated ammonia and hydrogen sulfide, along with a large fraction of water, flow to downstream unit operations as a vapor for further treatment. The stripped water may be disposed of as wastewater, or if it meets specifications, it may be used in other process units in the refinery, such as the crude oil desalter. A typical, simple sour water stripper process flow diagram is shown in Figure 1.

Different variations of the process flow shown in Figure 1 exist. Two frequently encountered differences are:

1. The addition of live steam into the column instead of a steam reboiler. Live steam will not foul or have maintenance issues that would be associated with the steam reboiler in a sour water stripper, but all of the steam introduced into the stripper will need to be made up in the facility's steam system with fresh steam and additional stripped water will need to be disposed of in one manner or another.

2. A pumparound system in the top of the sour water stripper instead of the conventional overhead condenser and reflux drum. In this design, a stream of water from the stripper is cooled and pumped to the top of the sour water stripper to maintain the overheads temperature from the stripper at the same temperature it would be leaving the reflux drum in the conventional design. This design avoids the need for the stripper overhead condenser, which can be an expensive and maintenance-intensive piece of equipment. The downside to this option is that additional height is needed in the sour water stripper for the cooling section, and the liquid pumparound equipment is made of upgraded metallurgy.

The sour water stripper and associated equipment are not typically revenue generators in any facility, but, at the same time, the unit operation is critical to the rest of the facility's operation, since most of the sour water in the facility has to be treated in the sour water stripper before it can be reused or processed further. The sour water fed to the sour water stripper will also change over time, with increasing or decreasing amounts of $NH_3$ and $H_2S$ present in the water and overall water flow rates varying, sometimes as frequently as day to day. So, the designer of the sour water stripper is challenged to design a flexible and robust system that can meet a variety of different feed conditions while also minimizing the cost of the equipment. Above all, the sour water stripper cannot be a bottleneck in the overall facility and must strip the sour water reliably in all operating conditions.

There is a long history of technical papers that thoroughly discuss many aspects of sour water stripping [2] [3] [4] [5] [6] [7]. This article is not meant to be a comprehensive review of sour water stripping. Rather, this article reviews a few of the key design choices available for the sour water stripper system, and then specifically focuses on some of the internals of the sour water stripper tower itself. The choice of internals in the sour water stripper can be difficult, with a range of different sources available in the literature, and few very thorough technical analyses completed to guide the designer to the "right" solution. The remainder of Part 2 of this article focuses on the design of packed towers for sour water strippers and commonly occurring operational issues in sour water stripper systems.

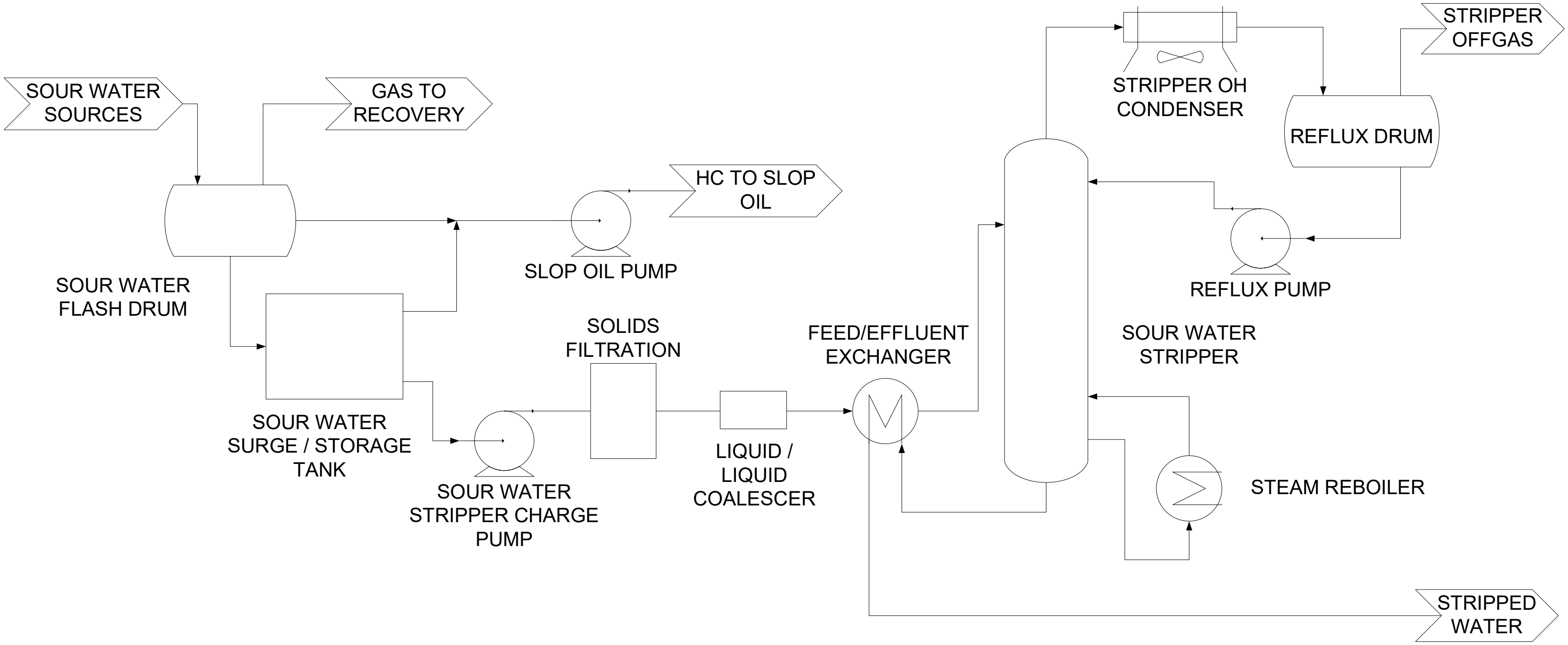


**Figure 1. Simplified Process Flow Diagram for Sour Water Stripper.**

# 2 Packed Tower Design for Sour Water Strippers

Packed towers in sour water stripper service are not as frequently encountered as trayed towers (see Part 1 of this two-part series for discussion of trayed strippers) but have been designed and operated successfully in units processing relatively clean water [8]. Packed sour water strippers may be used instead of trays for some of the following reasons:

- Familiarity – the facility may already have experience with operating packed sour water strippers;
- Pressure drop – the possibility of achieving a lower pressure drop with a packed column may have benefits for some systems;
- Cost – packed columns may be perceived to be less expensive than trayed columns, including the column itself and internals;
- Wider operating window - packing may allow more turndown, which could be important for refineries who must run at low rates for a period of time or who switch to crudes containing much less sulfur and nitrogen.
- Equipment re-use – a facility may be able to reuse a packed column from another process as the sour water stripper, or upgrade performance of an existing packed sour water stripper by upgrading the internals (e.g., such as distributor[s], packing, and etc.).
- Size – it may be easier to use packing for small or very small sour water strippers, as discussed during the question-and-answer portion of a recent trade symposium [1].

However, the major drawback to packed towers is that the packing can trap particulate matter as the sour water flows down the packed section. Over time, the packed sections of the tower can become fouled, and maldistribution across the bed(s) of packing may result. Pretreatment of the sour water with the separation equipment, as described in the prior Part 1 of this two-part article, is thus very important. It is also critical that fouling-resistant distributors and packing be used in the stripper.

### *2.1.1 Liquid Distributors*

Perhaps most importantly, distributors designed for fouling service are essential for successful operation of packed sour water strippers. Maldistribution of liquid in the top of the sour water stripper will negatively impact the efficiency of the entire stripper. Redistribution by the packing will not be able to overcome any maldistribution from the distributor.

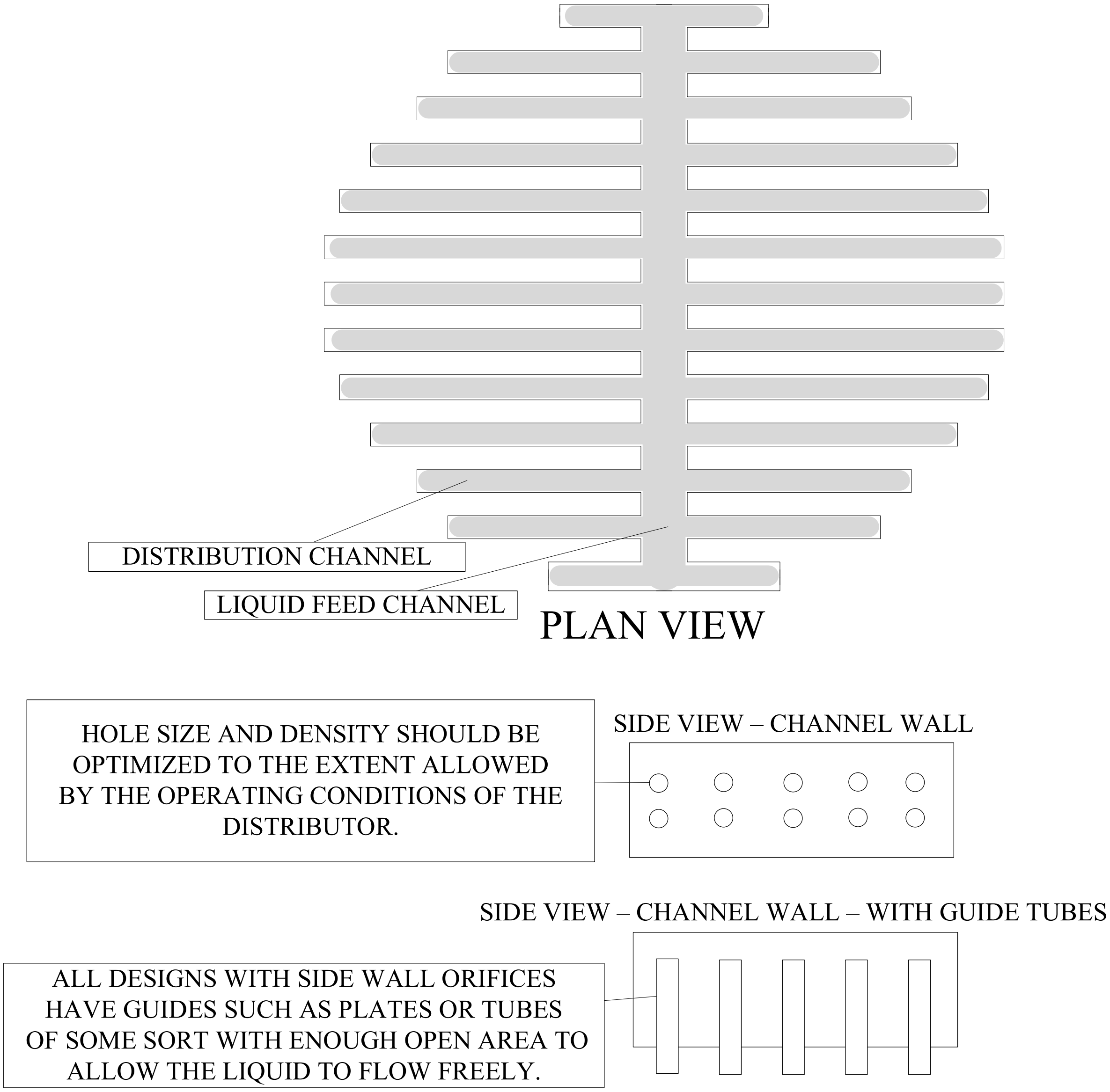
As such, there are trade-offs with liquid distributors that need to be considered to avoid the tendency to plug and foul while also providing adequate distribution of liquid over the packing. General recommendations for liquid distributors in sour water service include:

- Using larger orifices to minimize fouling and plugging of orifices;
- Reducing the number of drip points (generally an effect of using larger orifices, but not less than 5 points per $ft^2$);
- Using orifices in the sides of the distributor walls and not at the bottom; and
- Maintaining levelness of the distributor in designs that use gravity driving force.

Several different types of distributors that could be used in sour water service are described below. A vendor should be contacted to review the specific sour water application and make a recommendation on the type of distributor most suitable for that service.

Channel-Type Distributor

Figure 2 shows an example of a channel-type distributor used in sour water stripping. The channel-type distributor has holes in the sides of the distribution channels. This type of distributor is considered to be plugging resistant, with generally good overall distribution. The holes in the distribution channels should be as large as possible given the minimum drip point density allowed by the distributor design. All models have guides of some sort such as plates, drip tubes, etc. The guides are critical for good distribution. Channel wall designs are illustrated below.



PLAN VIEW

SIDE VIEW – CHANNEL WALL

HOLE SIZE AND DENSITY SHOULD BE OPTIMIZED TO THE EXTENT ALLOWED BY THE OPERATING CONDITIONS OF THE DISTRIBUTOR.

SIDE VIEW – CHANNEL WALL – WITH GUIDE TUBES

ALL DESIGNS WITH SIDE WALL ORIFICES HAVE GUIDES SUCH AS PLATES OR TUBES OF SOME SORT WITH ENOUGH OPEN AREA TO ALLOW THE LIQUID TO FLOW FREELY.

**Figure 2. Example Channel-Type Distributor**

## Weir Riser Pan Distributor

Figure 3 shows an example of a weir riser pan distributor. This type of distributor is used for smaller diameter (~12”-48”) towers in highly fouling service. The distributor is relatively inexpensive. As shown in the figure, the weirs serve as both liquid downcomers and vapor risers. A v-notch allows for distribution of a large range of liquid flow rates. This type of distributor design is used with heavily contaminated liquids and high fouling service. However, it does not provide as good of distribution as some other designs. Although the figure shows a v-notch, a rectangular notch is preferred.

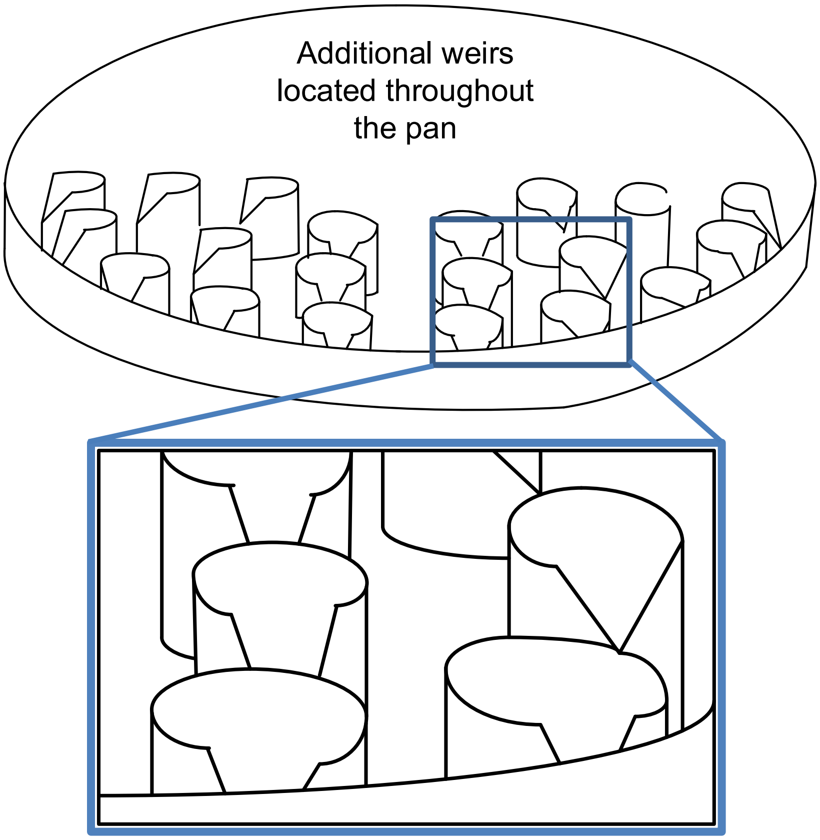
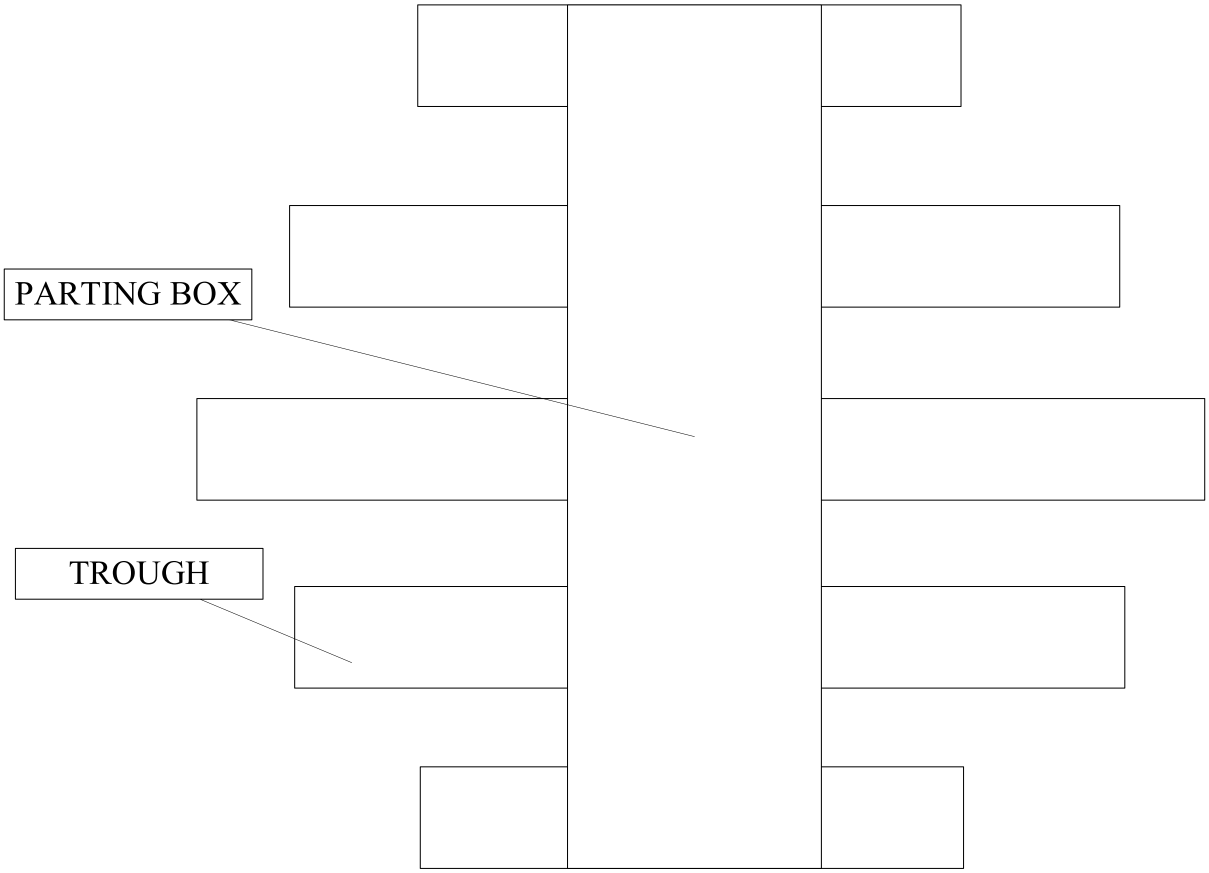


**Figure 3. Example Weir Riser Pan Distributor**

## Trough Distributor

Trough-style distributors with notches in the trough wall have improved fouling resistance and have been proven to be suitable for sour water strippers. A trough-style distributor will usually have the liquid feed into a parting box that distributes the liquid to individual troughs, and then liquid flows out of the individual troughs through vertical rectangular slots (or notches) cut into the side walls of the trough. Figure 4 shows a sketch of a typical trough distributor with a single parting box.

The parting box feeds liquid to the troughs through windows cut into the parting box wall, so the entire distributor is gravity fed. Notches in the distributor must be large to mitigate fouling concerns, and this limits the efficiency of the distributor somewhat. The notches have a vertical rectangular slot with a V at the top for overflow. Installing the distributor on a level plane is critical to ensure the distributor wets the packing below evenly; as mentioned above, any poor liquid distribution in the distributor will negatively impact the efficiency of the entire packed bed.



PLAN VIEW

SIDE VIEW OF TROUGH WALL

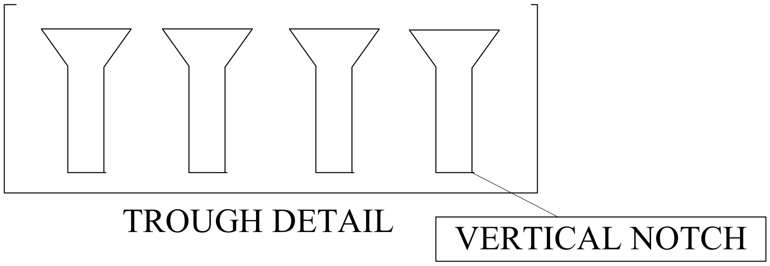


**Figure 4. Sketch of Trough Style Distributor**

Spray Nozzle Distributor

A spray nozzle distributor is shown in Figure 5. Spray nozzle distributors have been proven in various severe fouling services in refinery units. Although, per the question-and-answer portion of a recent industry symposium [1], opinions vary as to whether spray nozzle distributors should be used in the rectifying part of a sour water stripper (as opposed to used in a pumparound condenser, if present), this type of distributor is relatively familiar to refiners, which is why such a distributor is discussed here. In order to use this type of distributor, a higher-pressure liquid source is required. The design typically uses nozzles with the maximum amount of free-passage available and often in a full cone spiral design (see Figure 6). It will have poorer distribution than some of the other distributors mentioned in this paper but can be more fouling resistant.

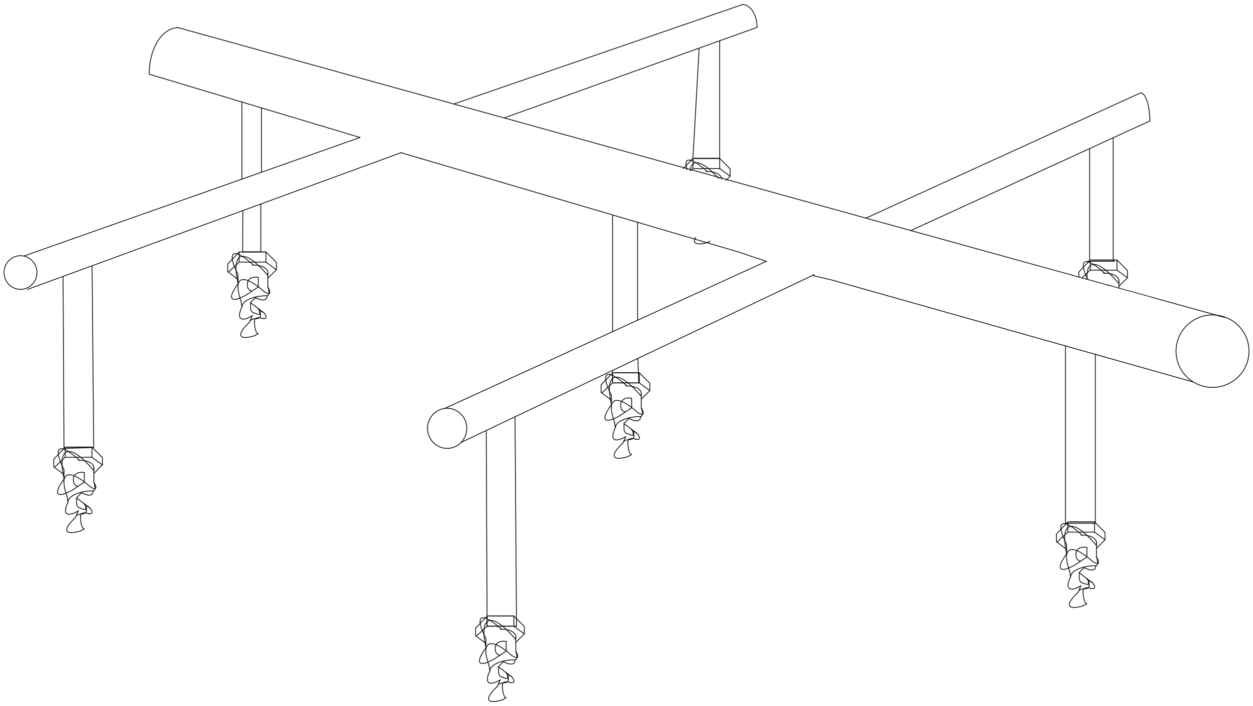


**Figure 5. Example Spray Header Liquid Distributor**

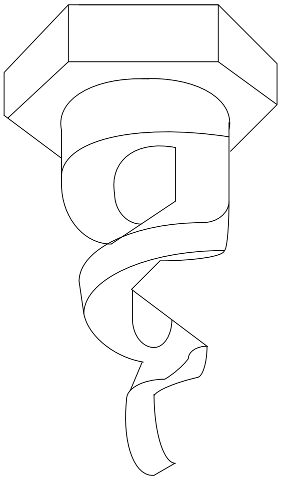


**Figure 6. Example Full Cone Spray Nozzle with Maximum Free Passage**

Liquid Distributor Comparison

Table 1 shows a simplified example table of characteristics of the liquid distributors described previously based, in part, on information in the literature [9]. Specific vendor designs may vary but will generally have these relative characteristics.

**Table 1. Comparison of Liquid Distributors for Sour Water Strippers [9]**

| Parameter | Channel | Trough | Weir Riser Pan | Spray |
|---|---|---|---|---|
| Driving force | Gravity | Gravity | Gravity | Pressure |
| Tower size | Typically medium to large | Typically medium to large | Typically small | Any |
| Liquid distribution quality (of those listed) | Best | Lower | Lower | Lower |
| Propensity to plug | Low to medium | Low | Low | Low to medium (depending on nozzle) |
| Must be installed almost perfectly level | Yes | Yes | Yes | No |
| Requires precise nozzle aiming | No | No | No | Yes |

### *2.1.2 Packing HETP*

Packed tower design in sour water strippers will run into the same issue encountered in trayed towers when considering the efficiency of the trays. In this case, the efficiency of the separation in a packed tower is represented in some cases by the Height of an Equivalent Theoretical Plate, or HETP. Similar to tray efficiency, HETP is a chemical engineering factor that is not static from one separation to another, or even from one packed bed to another in the same tower.

Packed towers in sour water stripper service generally use dumped (random) packing. HETP values for these types of packing are available from many of the vendors. Published HETP values are not specific to sour water stripper operations. If vendor-published general HETP values are used without considering the conditions that could be present in a sour water stripper, the system will not likely work correctly or for long. The mass transfer limitations must be taken into account.

Rules of thumb for packing have been offered in discussions at prior Brimstone Sulfur Recovery Symposia, and Trimeric has discussed these in conversations with a number of refinery SMEs. A rule of thumb for 2”, second-generation (e.g., Pall ring) or third-generation packing (e.g., IMTP) is to use 2 feet of packing depth per actual tray. Given the previous rule of thumb for trays (3 actual trays per theoretical stage in sour water stripper service) and assuming a tray spacing of 24”, this rule of thumb makes the height of packing the same as the height of trays that would have been present, if trays had been chosen. If one assumes that third-generation packing has similar efficiency to second-generation packing, then the rule of thumb seems applicable to both generations. However, the rule of thumb may be overly conservative. For example, one should nominally see an increase in capacity, or an increase in efficiency, or possibly both, when going from second-generation packing to third. Also, as noted below, better efficiency may be possible if the sour water is as clean as possible (i.e., if good feed preparation steps have been used) and if the liquid distribution quality is as good as possible. One author reported going from 2” Pall rings (second generation) to 1.5” IMTP (third generation) packing and achieving a significant improvement in efficiency in the same bed height and capacity [5].

Table 2 shows HETP values from the literature and from three actual operating sour water strippers. The data show relatively good agreement between the actual HETP and published HETP data for Source 2 (0.7 to 0.9 ratio) and Source 3 (1.1 and 1.3 ratio). However, the actual/experienced HETP for Source 1 was 2+ times the published HETP. There may be several reasons for this. Discussions with the author for Source 3 indicated that a reasonably good distributor (in this case meaning good balance of liquid distribution and low fouling tendency) was used in the stripper. Source 1 was known to have a poorer distributor type (not one of those mentioned previously). Source 1 also had other issues, including areas of plugged packing in sections of the tower. Furthermore, conditioning of the feed sour water may have been different between the sources - the literature discussing Source 3 mentions “minimal historical fouling and foaming issues” [5], so it may have had a cleaner sour water feed stream.

Table 2 also shows the ratio of the SME Design HETP to the vendor/published HETP. This factor ranged from 1.8 to 2.4, indicating that many choose to use a much larger HETP, conservatively increasing the packing bed requirements and sizing of sour water strippers.

**Table 2. HETP Comparison – Actual Operation.**

| **Parameter** | **Source 1** | **Source 2 (API DRW, Ch 15, 3)** [10] | **Source 3 (Stavros, 2013)** [5] |
|---|---|---|---|
| Packing type | Small diameter ring-type packing | 1" Pallring | 1.5" Specialty |
| Actual HETP, inches | More than 34" | 13 | 21 |
| Vendor/literature published HETP, inches | ~17 | 15,17, 19 | 20,16 |
| Ratio of Actual HETP to Published HETP | 2+ | 0.9, 0.8, 0.7 | 1.1, 1.3 |
| Ratio of SME Design HETP to Published HETP | ~1.8 to 2.4 | | |

### *2.1.3 Packing Recommendations*

Overall, the following may be useful when considering using packing in sour water stripping service.

1. Distributors should seek to balance a fouling resistant design with good liquid distribution (adequate drip point density); trough-style liquid distributors with large liquid openings in the side-walls of the trough (either rectangular-notched or round holes) have given good service in this application.

2. Packing should be of an open design without small openings to minimize the potential for fouling of the packing. The major packing vendors offer such open packing, some explicitly marketed for sour water strippers.

3. HETP values published in vendor literature or correlations provided in literature should not be used directly for estimating required packing bed(s) depth. It is necessary to consider the potential for fouling and efficiency loss in the sour water stripper packing. Although some sour water systems have experienced actual HETPs approaching vendor/literature HETP values, it is suspected that those systems were fed sour water that was cleaner than typical, perhaps due to practices like those mentioned in note 4 below. Experience and good engineering judgment must be used in estimating HETP that will be experienced in the end, which should include evaluation of the mass transfer.

4. Sour water feed conditioning systems are likely even more critical for a packed sour water stripper than they are for a trayed sour water stripper. Adequate 3-phase separation in all separators in the process (even the reflux drum, if installed) is recommended. Adequate settling time in the sour water surge tank is also recommended in addition to

the particulate filter and liquid coalescer. (See Part 1 of this two-part article, which was published in a prior edition of this magazine.)

## 3 Issues Encountered in Operation

There are a wide range of operating problems that can occur in a sour water stripper system. A select few are discussed in the subsections below.

### 3.1 Fouling of Sour Water Stripper Internals

Sour water stripper internals can foul from many different materials. Corrosion products can accumulate on the tray or in the packing and cause fouling.

Even with all the preventative measures discussed in Part 1 of this two-part article, hydrocarbons and solids may still enter and foul the sour water stripper internals. It has also been reported in the literature [7] that because of the high vapor pressure of water in the stripper, volatile hydrocarbons will evaporate with the overhead gas. As a result, removal of lighter hydrocarbons may make heavier hydrocarbons less soluble in the water and too viscous to flow properly at the sour water stripper temperature [7]. The heavy hydrocarbons collect along with corrosion particulate and other solids to form a fouling layer on trays or packing [7].

If the sour water stripper is underperforming and other more routine process checks on the system have not identified a cause, a gamma scan can be conducted to determine if the internals of the tower are damaged or severely fouled. A gamma scan generates a density profile of the column that can be used to identify the integrity of internals and column operating conditions. Scans have shown columns where entire packed sections were missing or lower than expected. Maldistribution of liquid in the column can also be demonstrated via the scans. Maldistribution of liquid in the column will reduce the efficiency of the packing. Issues with the integrity of tray towers can also be identified.

### 3.2 Maintenance and Monitoring Requirements

Routine maintenance and cleaning of equipment may be prudent to remove fouling and particulate and improve the run time of the sour water stripper system. For example, exchangers with bypasses can be periodically cleaned on-line. Exchangers used in other processes that transfer heat between a sour water stream and a hydrocarbon stream should be inspected for leaks to minimize the potential for sending hydrocarbon-contaminated water to the sour water stripper system.

The sour water stripper tower could also be washed occasionally, if there is enough storage for the sour water at the plant. Weak acid and base washes can remove scale and detergent washes can remove hydrocarbons [11].

The hydrocarbon and liquid levels in the flash drum and surge tank should be routinely visually checked to ensure they are at the proper heights and that hydrocarbons are not entering the stripper. Level controls and interface level controllers in the flash drum and surge tank should be inspected on a routine basis to make sure they are working appropriately.

The sour water stripper overhead lines should be periodically examined for cold areas (<~180F) to prevent salts from depositing. The overhead lines need to be steam traced and insulated or steam jacketed.

Process instrumentation should be routinely checked for accurate readings to aid in diagnosing potential sour water stripper problems. The column differential pressure, overhead temperature, and process water flow are important parameters to monitor [11].

In some cases, chemical agents (dispersants, scale/corrosion inhibitors, and cleaning solutions) may be able to help control/remove fouling from residue of hydrocarbons, salts, and corrosion byproducts.

Solid and liquid material from the filter, liquid coalescer or other equipment could be analyzed to determine the type and source of fouling. Routine samples of the sour water and stripped water should be taken to help identify issues in performance.

### 3.3 Salt Solids Formation

The formation of salt solids is another concern in sour water strippers. For example, in sour water strippers that remove $H_2S$ and $NH_3$, ammonium bisulfide ($NH_4HS$) solids may form in the overheads line. When the acid gas condenses, the reflux water may contain a high concentration of $NH_4HS$ that can lead to corrosion and salt solids formation. A sour water stripper with reflux usually has higher concentrations of $NH_4HS$, but pumparound systems can also be impacted by this type of corrosion [11]. Corrosion increases with increasing $NH_4HS$ concentration and velocity. Carbon steel is often acceptable when the $NH_4HS$ concentration is less than about 2 wt%. Carbon steel is marginal when the concentration is between 2 wt% and 8 wt%. Above 8 wt%, carbon steel is generally viewed as unacceptable, and stainless steel or other higher alloys may be required [12]. The overhead temperature is generally kept at or above roughly 180F to avoid the formation of ammonium bisulfide solids that can plug lines and equipment [7] [13].

Other salt solids can be present in sour water stripper systems as well. Salt solids can form if the water feed is hard - contains a significant amount of calcium and magnesium. This may occur if low quality wash water is used in the equipment generating the sour water, among other reasons.

Ammonium carbamate ($NH_4CO_2NH_2$), ammonium bicarbonate ($NH_4HCO_3$), and ammonium carbonate ($(NH_4)_2CO_3$) solids can form if $CO_2$ is present. Ammonium carbonate and bicarbonate will sublime from the stripper overhead gas at temperatures of 130-167 °F [11]. The deposition temperature depends on the partial pressures of the acid gas components ($NH_3$, $H_2S$, $CO_2$) and $H_2O$ in the stream. Deposition curves exist in the literature for many of these salts. It is considered best practice to operate the sour water stripper a safe margin above the estimated sublimation/deposition temperature.

## 4 Summary

Stripping sour water is a demanding process in a refinery or gas treating facility. The sour water will contain a multitude of contaminants in addition to the ammonia and hydrogen sulfide stripped out of the water in the process. These contaminants make reliable operation of the sour water stripper a challenge. Part 1 described the equipment upstream of the sour water stripper that reduces fouling and foaming issues in the stripper tower, including the sour water flash drum, surge / storage tank, and solids filtration / coalescing filters. Part 1 also presented design guidance to account for foaming in the stripper and optimum feed location for the sour water; the design features for trayed columns were also reviewed in detail. Part 2 focused on the internals specified for sour water strippers with a packed tower design. The types of liquid distributors used in sour water stripping service were discussed, along with a comparison of HETP values from vendors, actual operation, and subject matter experts. Other packing recommendations were provided, and operating issues encountered in sour water stripper systems were also discussed in Part 2. Even with all the upstream equipment designed to remove contaminants, corrosion products can still accumulate on the tower internals and cause fouling. Salt solids formation such as ammonium bisulfide, ammonium carbamate, and ammonium bicarbonate solids can also occur at cool spots in the overheads line, requiring proper temperature management. Regular maintenance and monitoring can improve sour water stripper performance and extend the run time for the system, which will benefit overall refinery operations.

## 5 Works Cited

[1] K. McIntush, J. Farone, B. Piggott and C. Beitler, "Specifying Internals in Sour Water Strippers," Brimstone Sulfur Recovery Symposium (Virtual Vail), 2020.

[2] B. Scott, "Processes for Treating Refinery Sour Waters," Brimstone Sulfur Recovery Symposium, Vail, CO, 1995.

[3] J. Asquith and A. Moore, "Sour Water Processing -- Balancing Needs," Brimstone Sulfur Recovery Symposium, Vail, CO, 2000.

[4] D. Stevens, A. Mosher and D. Ogg, "Fundamentals of Sour Water Stripping," Brimstone Sulfur Recovery Symposium, Vail, CO, 2007.

[5] J. Stavros and A. Keller, "Reducing Nitrates in Refinery Wastewater," Brimstone Sulfur Recovery Symposium, Vail, CO, 2013.

[6] N. Hatcher, R. Alvis and R. Weiland, "Sour Water Stripper Performance in the Prescence of Heat Stable Salts," Brimstone Sulfur Recovery Symposium, Vail, CO, 2012.

[7] A. Keller, "Fundamentals of Sour Water Strippers," Brimstone Sulfur Recovery Symposium, Vail, CO, 2015.

[8] R. H. Weiland and N. A. Hatcher, "Sour Water Strippers Exposed," in *Laurance Reid Gas Conditioning Conference*, Norman, OK, 2012.

[9] Kister, H., Distillation Operation, McGraw-Hill, 1990.

[10] American Petroleum Institute, Division of Refining, Manual on disposal of refinery wastes: volume on liquid wastes (Chapters 10 and 15), Washington, DC: 1st ed., 1969.

[11] P. Le Grange, "Operational Challenges in Sour Water Stripping," *www.digitalrefining.com/article/1002335,* 2009.

[12] J. Dobis, J. Cantwell and M. Prager, "Damage Mechanisms Affecting Fixed Equipment in the Refining Industry," Welding Research Council, Bulletin 489, 2004.

[13] T. Armstrong, B. Scott, K. Taylor and A. Garder, "Sour Water Stripping," *Today's Refinery,* June 1996.