# How to Make a $20,000 Expense

# EVAPORATE

*A discussion of thermal evaporation technology reveals how one company saved a bundle on waste disposal costs.*

by Timothy S. Bellingham and William C. Noble

A Midwestern manufacturer was faced with a wastewater discharge problem from their parts washers. The local publicly owned treatment works (POTW) found that the discharge from this process frequently exceeded their grease and oil limits of 100 ppm and after repeated warnings threatened to apply a surcharge for each discharge that exceeded the limits. This naturally motivated the company to seek a solution. However, after evaluating several oil/water separators and filtration equipment, the company selected one and approached the POTW for their approval only to find that the limits for zinc had been severely lowered and the separation and filtration equipment would not meet this requirement.

## Taking Inventory

This trouble with the POTW prompted management to do an immediate facility survey and disposal audit. Through this process, it was determined that they were hauling 10,000 gallons per year of computer numerical control (CNC) machine coolant at $0.86 per gallon and 6000 gallons per year of air compressor condensate at $0.40 per gallon. They were also using an oil dry product on their floors that was becoming an issue with the local landfill. Plant maintenance had wanted to buy an automatic floor scrubber to eliminate the oil dry but were denied because the water would have needed to be hauled off-site for disposal; it was too costly because the washing schedule would generate about 12,000 gallons per year.

Finally, they found that their parts washers were generating 14,000 gallons of wastewater per year. With zinc levels that were above the limits for discharge and the requirement for constant monitoring with the resulting surcharges from the POTW ($3,000 per occurrence), their only alternative was to have the waste hauled off-site for disposal. That would mean a significant increase in operating cost. In addition, management was concerned about the potential liability of hauling an annual volume of 42,000 gallons over the highway.

## Crunching the Numbers

The company elected to investigate a 15-gallon-per-hour evaporator. The supplier of the evaporator ran a functional test showing that the total annual volume would be reduced by

| Cost of 42,000 gallons per year being hauled off-site for disposal: | |
|---|---|
| 10,000 gallons of coolant @ $0.86/gallon: | $8600 |
| 12,000 gallons of automatic floor scrubber @ $0.86/gallon: | $10,320 |
| 6000 gallons of air compressor condensate @ $0.40/gallon: | $2400 |
| 14,000 gallons of parts cleaning wastewater @ $0.40/gallon: | $5600 |
| Annual off-site hauling cost: | $26,920 |

| Sewer discharge costs: | |
|---|---|
| Annual sewer connection fee: | $5000 |
| Monitoring and testing fees: | $1200 |
| Surcharge per occurrence: | $3000 |

| Evaporation system costs: | |
|---|---|
| Operating cost (42,000 gallons @ $.042/gallon; Natural gas fuel @ $.35 per therm) | $1764 |
| 6% residue hauling cost = 2520 gallons @ $0.86/gallon: | $2167 |
| Maintenance cost = 12 man hours @ $30/hour: | $360 |
| Total annual operating cost: | $4291 |
| Total annual cost (including capital equipment cost of $18,230): | $22,521 |
| Payback: | 10 months |

**Figure 1.** Cost comparison between manufacturer's present process and evaporation system.

94%, and they determined that the installation would qualify for exemption under the state's air quality regulations.

The actual economics of utilizing the new system are detailed in **Figure 1**. Furthermore, because of the cost savings involved with the evaporation system, the company was able to:

- purchase the automatic floor scrubber and eliminate the oil dry product
- dump the parts washer baths more frequently, improving the quality-controlled cleanliness of the parts
- perform better machine coolant maintenance in their CNC department, eliminating some malodor and skin problems
- pay back their investment in 10 months
- eliminate sewer discharge and its compliance costs forever

Finally, any future changes in the company's manufacturing process would be accomplished with minimal concern over wastewater generation from the new process. Evaporation is not waste stream–specific and can accommodate fluctuations in waste stream constituents—fluctuations that would cause upsets with other waste treatment technologies. Therefore, the company gained flexibility in maximizing production efficiency and product quality without concerns over ever-tightening sewer discharge limits and compliance costs.

## How Does Evaporation Work?

Thermal evaporators (**Figure 2**, page 22), the most widely used evaporation technology, evaporate wastewater by bringing it to a full boil (212°F) at normal atmospheric pressure. The resultant phase change to steam means that the evaporation rate is not affected by changes in the relative humidity (wet bulb condition) of the atmosphere. While it may initially appear to be "simply boiling water," it is actually an ever-changing, dynamic concentration of chemicals at boiling temperature. For this reason, equipment design, safety features, and process controls are critical; the design philosophy will have a direct effect on efficiency, performance, and maintenance costs.

## Heating Methods

The simplicity of boiling water at normal atmospheric pressure is a major reason why thermal evaporation is so widely used. However, within this category are different designs that apply heat in different ways. Each of these distinct designs will have a dramatic impact on consistent performance, consistent results, maintenance costs, and safety.

All parts cleaning waste streams contain oils and suspended or dissolved solids. Evaporating the water causes emulsions to break and suspended and dissolved solids to reach saturation and fall out of solution. When heat is applied through the bottom, the evaporation rate can be diminished by these settled solids. Heat applied through the sidewalls or by direct fire will be affected by emulsified and floating oils. And with submerged combustion where the combustion gas is turbulently driven through waste, foaming is often problematic.

The above heating concerns can be eliminated through immersion heating, the method preferred by chemical engineers for process tanks, boilers, and hot water heaters. Immersion heating is effective in evaporation because the elevated, tubular design allows solids to fall harmlessly past the heat exchanger and collect underneath, where they cannot affect the heat transfer to the water. A properly designed immersion heating system with design features and component selection will ensure the heat exchanger is always in water by elevating the heat exchanger away from the tank bottom, thus preventing immersion in settled solids. As the fluid is evaporated and the water level drops, level controls that detect an oil/water interface will prevent floating oil from coming in contact with the heat transfer surface.

## Emission and Safety Controls

Emission control using mist elimination

The solution is fed to the tank (a) in either a batch or continuous mode (automatic fill), then is heated to boiling (212°F) by a serpentine gas-fired heat exchanger (b). The blower (h) draws in ambient air through both the burner (c) and a sized opening in the tank (d). Air is drawn across the surface of the heated liquid (e), sweeping away water vapor as the bubbles break the surface. This moisture-saturated air and the flue gases leave the tank via separate passageways. The moisture-saturated air passes through a coalescer-style mist eliminator system, which removes oil mist and droplets, allowing only the steam to pass through. The steam and the flue gases are joined together at the blower entrance (f,g). The two environmentally safe air streams are mixed in the blower (h) and are released up the stack (i). Free oils and oils whose emulsions have been thermally broken float to the surface. They are then removed by actuating a simple switch. These oils exit via an overflow trough (j) into an external waste receptacle. Liquid residue concentrates in the tank and precipitated solids collect in the sloping trough. Concentrate and solids are easily removed via a convenient clean-out port (k). A full-function evaporator control enclosure (l) and system process control (m) indicate various operating conditions (normal, shutdown, etc).

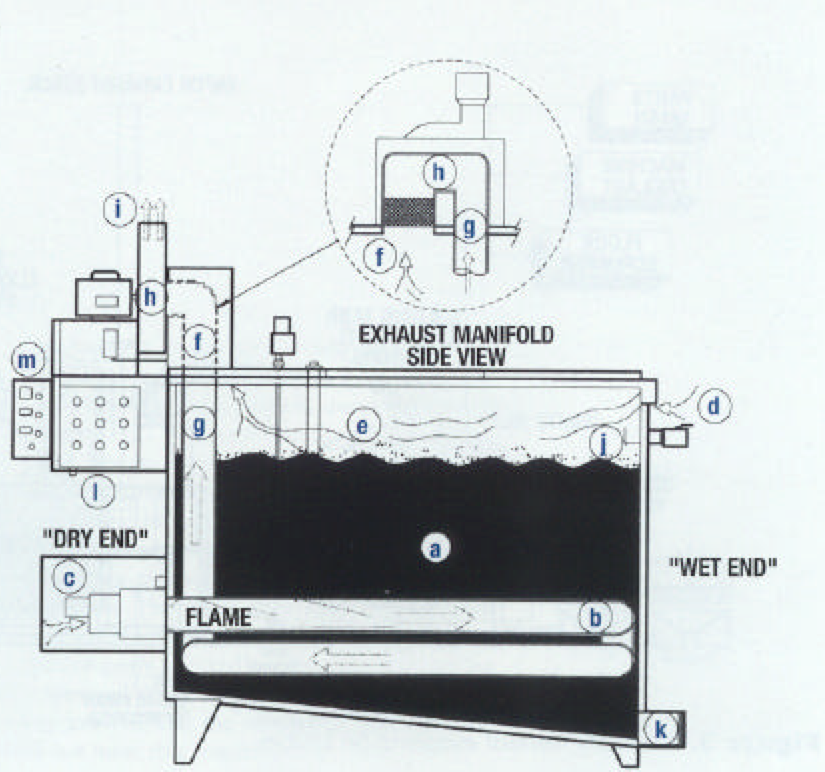


**Figure 2.** A typical thermal evaporator and its principles of operation.

technology, foam detection, and foam control is an important issue when considering evaporation. Foam contains chemistry and oils. If this oily foam is allowed to build up in the evaporator without control or detection, it can overflow out of the system or be sent up the exhaust stack.

An optimum mist elimination system (**Figure 2f-h**) will include foam detecting level sensors and controls to protect the integrity of the tank freeboard area, which protects the integrity of the mist eliminator system. The mist eliminator pad should have a tight compression fit to prevent blow-by of mist droplets. It must be located in an area where it cannot be flooded by foam. Of note: The manufacturers of mist elimination devices do not recommend using them as foam breakers.

A well-constructed evaporator will be insulated to lessen heat losses in the process tank and ensure it does not contribute to the ambient air temperature in the area. Furthermore, because thermal evaporators are usually gas-fired, either by natural gas or liquid propane, they must employ a "belt and suspenders" approach to safety. For each critical primary sensor, there must be a redundant sensor that uses a different technology to monitor the same critical function. This approach will eliminate the risk of common mode failure. The control panel should provide an instantaneous, easily understood operator feedback on the critical operating and shutdown conditions of the equipment.

## Installation Issues

Process and labor considerations will determine how a company may wish to configure its evaporation system. For example, with a small amount of wastewater, a manual fill system may suffice whereby wastewater is collected in drums and then directly transferred to the evaporator. In a process where large volumes and/or several waste streams are brought to a common holding tank, however, an automatic system may be desirable. There are many different system configurations for an evaporator, but **Figure 3** (page 24) illustrates the most common.

Good chemical engineering practices will determine holding tank sizes, pumps, liquid flow, and pretreatment (if necessary), but the installation of the evaporator is a very simple process. With floor space at a premium in most plants, an evaporator's small footprint and minimal auxiliary equipment requirements mean greater flexibility when integrating the system into an existing floor plan. Because there is no connection to sewer, evaporators can be located where it is most convenient for the user.

## Environmental Compliance

Evaporation is viewed favorably by regulatory agencies. In addition to wastewater minimization, it can simplify the conversion from solvent to aqueous cleaning. Recycling of concentrated materials when appropriate completes the environmentally friendly process.

Evaporation is governed by air quality issues, and every state in the US and most foreign countries have air quality regulations. With proper documentation and waste stream testing, permitting is available, with some states even providing diminimus levels for permit exemptions. The equipment supplier should at a minimum provide guidance in the application process and optimally offer the option of completing all necessary paperwork. There are also many states with exemptions from hazardous waste treatment regulations, under certain conditions. Again, the supplier should be knowledgeable about obtaining the appropriate approvals needed for the compliant evaporation of hazardous waste streams.

## System Enhancements

While most well-designed evaporators will operate with minimal attention, process management and process control are becoming highly desirable. By providing on the evaporator additional levels of con-

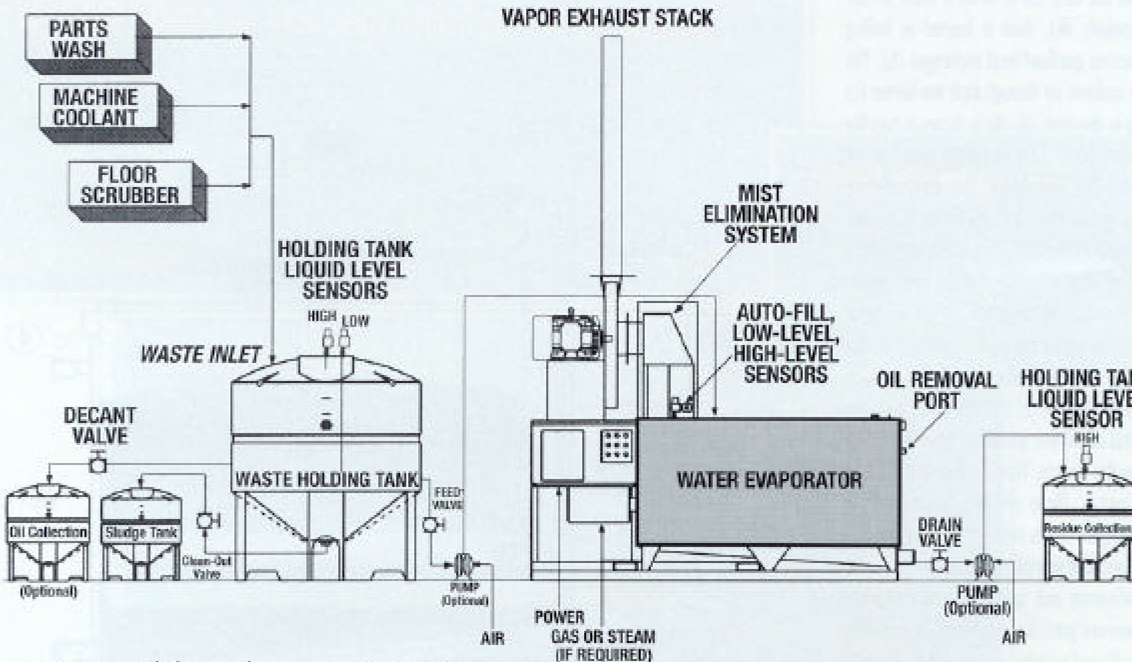


**Figure 3.** A typical thermal evaporation system.

trol that monitor gallons processed, time at boiling temperature, or bath temperature itself, concentration of the chemistry can be maximized, greatly reducing the residue volume and its disposal cost.

In certain instances, automatic draining via a PLC-based control system is desirable. An example might be salt brine solutions where saturation occurs at lower reduction concentrations. In an evaporator with a high evaporation rate and low reductions/concentrations, the short operating cycle may require that the system be drained once or twice in a 24-hour time period. Automatic draining will control the process from start to finish, removing the residue and restarting the next cycle, all without operator attention. Systems can be designed that place a phone call if trouble occurs, or call the waste hauler as the residue-receiving vessel nears its capacity.

Systems are available that condense the steam vapor and return it to process for reuse. These systems meet the requirements of certain hazardous waste treatment regulations where close-looping is required as a condition of regulatory approval. They have also been highly successful in processing radioactive wastewaters.

## But Will It Work for You?

A major concern for anyone purchasing waste treatment technology of any kind is: "How do I know it will work?" The answer: a functional test, also known as a "pilot" test. The experience level of the organization and technical staff performing the test, in-house protocols, and the consistent quality of the results are vital for predicting success.

Prior to the point of sale, functional testing on the actual waste will reveal critical information needed for both cost justification and equipment selection. It will also identify any conditions that might disqualify the waste as a candidate for evaporation. Saturation points, viscosity changes, and polymeric materials that solidify when dewatered will be identified before a purchase is made. A comprehensive laboratory evaluation will provide significant information about the waste before, during, and after it has been evaporated. Both individual waste streams and a composite mixture of all the streams should be tested. Test results will enable the supplier to provide recommendations on materials of construction, operating procedures, foam control, solids separation, and oil removal. They will also provide an accurate forecast of residue volumes and clean-out schedules.

It is important to note that a functional pilot test performed by a specific supplier does not mean that the waste will behave the same way in another evaporator design. Furthermore, a laboratory analysis for constituents, while important to have for regulatory reasons, is not a functional test. Only a properly performed functional test will predict with great accuracy how the various chemistries and soils in the waste will change as they are dewatered at boiling temperature.

Provided functional testing confirms compatibility, a company can feel confident in their selection of evaporation technology. It is a versatile, cost effective, fully compliant way to solve wastewater disposal concerns for today, tomorrow, and beyond. Engineering, equipment design, and a supplier who will serve as a technical partner will ensure a well-integrated installation.

## About the Authors

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