Help Instruction File:

Reaction Tank Module Overview

Provided by the Office of Surface Mining Reclamation and Enforcement (OSMRE), the Pennsylvania Department of Protection (PADEP), the U.S. Geological Survey's (USGS) and the West Virginia Department of Environmental Protection (WVDEP).

Reaction Tank Module Overview

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1.0 Objective

The objectives of this overview are to: (1) Provide an understanding of the application of Reaction Tanks in mine drainage treatment and (2) Provide an overview of the Reaction Tank Module to guide users in developing an estimate of the cost to construct, this type of treatment system component. This module, as well as most of the other AMDTreat modules, can also be applied to reverse cost model existing systems and system components to establish and evaluate future financial and investment decisions.
The information is presented in two sections, **Overview and Application** and
Reaction Tank Module Overview.

2.0 Overview and Application

A basic understanding of the application and equipment requirements of a reaction tank is required to develop a treatment strategy using the AMDTreat software. These topics are discussed below followed by a discussion of the Reaction Tank module interface and functionality. The Overview and Application section is organized into three parts: (1) Functional Properties and (2) Equipment and Typical Treatment Configurations, and (3) Application.

2.1 Functional Properties

In mine water or wastewater treatment applications Reaction Tanks, also sometimes referred to as Reactor Tanks or Mix Tanks, serve a variety of functions and are designed in an assortment of configurations. In a general sense mine water treatment can be envisioned as an overall two-step process. The first of which involves chemical processes, such as, pH adjustment, oxidation, and precipitation. The second step comprises of physical processes, such as flocculation and sedimentation. Reaction Tanks are one of the main components where chemical treatment processes occur.

Listed below are some of the primary functions that Reaction Tanks facilitate in a typical mine drainage treatment system.

1. Introduction and mixing of treatment chemicals (both mixing and dissolving treatment chemicals)
2. Acidity Neutralization (pH adjustment)
3. Conversion of dissolved species to suspended solids (formation of oxides or oxyhydroxides) or in some cases formation of minerals such as Calcite ($CaCO_3$) or Gypsum ($CaSO_4$), although calcite and gypsum formation are typically considered a nuisance precipitation. Calcite or Gypsum formation in reaction tanks or other treatment components is an important consideration for systems designers and reviewers because these occurrences will result in additional system operational and maintenance costs related to cleaning and descaling of reaction tanks and other system components.
4. Blending or mixing of mine waters of variable flow or quality, if multiple sources are being treated.
5. Gas exchange with the atmosphere (O_2 and/or CO_2) **Note:** Decarbonation (CO_2 outgassing) and aeration/oxidation are discussed in detail in the Decarbonation Module Help File the reader is referred to that module for a more complete discussion.
6. Introduction and mixing of recirculated solids (sludge recirculation or High-Density Sludge [HDS] process) Note**:** Sludge recirculation is discussed in great detail under the Clarifier Module Help File and the reader is referred to that module for a complete discussion.

7. Heterogeneous iron oxidation and sorption of other metals such as Manganese and trace metals. Whereas suspended iron particles can, in some cases, promote additional metals removal. **Note:** Heterogeneous iron oxidation and sorption are discussed in detail in the PHREEQ Module Help File and the reader is referred to that module for a more complete discussion.

2.2 Typical Treatment Configurations

Mine drainage treatment reaction tanks are in general designed to function along the lines of one of two different design approaches. They are either designed as Continuous Stirred Tank Reactors (CSTR) or Plug Flow Reactors (PFR)

2.2.1 Continuous Stirred Tank Reactors

In mine drainage treatment, Continuous Stirred Tank Reactors (CSTR) are typically cylindrical tanks that are continuously agitated with a stirring system. Raw mine drainage enters at the top of one side of the tank and exists at the opposite side and a treatment reagent, such as Hydrated Lime, is added to the tank. A major assumption is the reagent is perfectly and instantly mixed and at steady state so conditions in the reactor do not vary with time. For example: Concentrations, temperature, etc. are uniform throughout the reactor and identical to the effluent.

It is assumed that the Lime being added is instantly and completely mixed. It is also assumed that continuous inflow mine water which is then dispersed and mixed with treatment reagents by either physical means, such as tank baffles or by mechanical means, such as mixers or by a combination of the two. In a 100% efficient, or "ideal" CSTR effluent water composition will equal to the composition of water within the reaction tank. Inefficiencies exist in all real world CSTRs as non-ideal hydraulic behavior such as short circuiting and dead spots do occur to some degree and designers must account for non-ideal conditions in their designs. The primary advantage offered by CSTR type reaction tanks is they offer very efficient treatment reagent mixing capabilities relative to Plug Flow Reaction Tanks (discussed below). They also buffer the effects of variable water quality entering the tank. One potential disadvantage of CSTR tanks results from the fact that individual water particles do not experience a uniform retention time and that an overall average of individual particle retention times represents the design retention time.

2.2.2 Plug Flow Tank Reactors

Plug Flow Tank Reactors (PFR) also provide for continuous inflow, however, in an "ideal" PFR no or minimal lateral mixing of water occurs. PFR reactors are configured to promote lateral movement of water through the tank similar to flow through a conduit or pipe. Very little mixing occurs parallel to flow direction. Mixing only occurs in areas perpendicular to flow direction. Effluent water composition is only comparable to waters contained in the final portion (downstream section) of the PFR. Unlike CSTR tanks individual water particles experience a uniform retention time which may benefit certain chemical reactions. PFR reactors are less conducive to mixing of treatment reagents with influent waters and are more difficult to manage in situations where influent flow or water chemistry is variable.

2.2.3 Batch Flow Tank Reactors

A third overall type of Reaction Tank design approach is the Complete Mix Batch Reactor (CMBR). This type of reaction tank is essentially a closed system in that no inflow or outflow is permitted into the tank. Fluid and reagent are added to a tank as a batch and the reaction proceeds for a specific period of time until the tank is emptied. Except for very low flow discharge scenarios that would also be employing some type of holding or equalization tank or pond this design approach would have limited applicability in mine drainage treatment. An example of a quasi-batch reactor used in mine drainage is the Caustic Soda siphon system. In variable flow systems, a tank fills with mine drainage and is dosed with a predetermined amount of Caustic Soda until a fill height is achieved that triggers a siphon to empty the batch of treated mine drainage to a settling pond. This system works well for variable flow discharges that contain a constant chemistry since the caustic dose remains constant for the volume of the tank.

2.3 Application

The current version of the Reaction Tank module in AMD Treat considers only a round baffled tank design that models a Continuous Stirred Tank Reactor (CSTR). Plug Flow Reactors (PFR) and Complete Mix Batch Reactors (CMBR) are not currently included in the program.

The CSTR reactor in the program is considered to be an "ideal" mixer, meaning that no short-circuiting of flow paths or "dead spots" exist within the tank. Consequently, users and system designers should make allowances and apply design safety factors to account for real world inefficiencies.

3.0 Reaction Tank Module Overview

3.1 Layout and Workflow

In general, inputs are on the left-hand side of the module and calculated outputs are on the right. The module inputs on the left-hand side are arranged into six sections: (1) Water Quality & Flow Input, (2) Round Baffled Reaction Tank Design, (3) Equipment Options and Foundation Conditions (4) Other Capital Cost Items (5) Annual Cost Items, and (6) Other Annual Items.

The workflow for the module is for users to begin at the top left-hand side. Enter the *Design Flow* and AMDTreat then calculates an initial tank sizing summary and related financial information, on the right-hand side of the Module, that is based upon the default value. Next, users select the *Round Baffled Reaction Tank Design and Equipment headings* to select and size treatment equipment. Additionally, users can use this section to specify the operational frequency and duration of the treatment system to ensure annual costs are correctly modeled. Finally, users can specify additional capital and annual costs not considered by the module under the *Other Capital Items, Annual Cost Input ($/Kw),* and *Other Annual Items* headings.

Module output is provided on the right-hand side of the module. Module outputs are arranged into four sections: (1) *Sizing Summary*, (2) *Capital Cost*, (3) *Annual Cost*, and (4) *Net Present Value*. The *Sizing Summary* section provides estimates of retention time, reaction tank sizing and volumetrics, mixer power specifications, land area estimates and foundation requirements. The estimated cost to construct and operate the Reaction Tank components is provided under the *Capital Cost* and *Annual Cost* headings.

Lastly, users can opt to conduct a Net Present Value (NPV) analysis to obtain the total cost to operate and maintain this treatment system component for a defined time period.

A general overview of the module input and output sections is presented below, however, users are directed to the numerous tool tips located in the module that provide additional detailed information, such as definitions of terminology. In most cases, the tool tips are accessed by clicking on the information icon ( ) in each of the subheadings in the module.

3.2 Module Inputs

3.2.1 Design Flow Input

The Flow Input section is where users specify the Design Flow. This flow rate is used to calculate the tank retention time for the tank size that has been selected in the next module input section entitled *Round Baffled Reaction Tank Design* so one must take careful consideration to be certain that the value chosen accurately depicts site conditions. Retention time is a critical factor that system designers must consider for sizing the appropriate reaction tank size. The appropriate retention time is dependent upon both raw water quality characteristics, the type of treatment reagent selected, the treatment pH and targeted treatment parameters (i.e. what combinations of Acidity, Iron, Manganese, Aluminum and others are desired to be treated) and the solubility and mixing characteristics of the treatment chemical(s) that are being proposed. The following brief examples will serve to illustrate how retention time selection should depend upon the overall treatment methodology.

In treatment systems that utilize Lime Products (Dry Lime or slurry), reaction tank retention time sizing must consider lime solubility limitations in addition to volumetric and dissolved metal species oxidation mix time considerations. Studies indicate that a minimum of 6 to 12 minutes of retention time is needed to achieve adequate dissolution of lime products. Lime product solubility characteristics are discussed in much greater detail in the AMDTreat Lime Products Help File.

Treatment systems that utilize more soluble treatment chemicals such as Sodium Hydroxide (NaOH) or Hydrogen Peroxide (H_2O_2) in most instances do not need to consider additional retention time beyond the time needed for adequate mixing with influent water and the time needed for dissolved metal species oxidation. Both of the above, NaOH and H_2O_2, example treatment chemicals are highly soluble.

Target treatment pH will also be a prime determining factor in choosing a Reaction Tank size that will provide adequate retention time. For example, if a target treatment pH of 7.5 is envisioned for iron oxidation in a reaction tank, the reaction tank size and corresponding retention time will need to be significantly larger than if a target treatment pH of 8.3 is envisioned. The Homogeneous Iron Oxidation Tool in the tools menu of AMDTreat and the associated Help File, will assist the user in evaluating needed additional retention times.

If sorption reactions or Heterogeneous Iron Oxidation, accommodated through the process of solids recirculation or other mechanisms is planned, Reaction Tank sizing and subsequent retention time targeted values will require further adjustment. The AMDTreat Heterogeneous Iron Oxidation Tool and the AMD Treat PHREEQ Module and their requisite Help Files will assist the user in adjusting the needed Reaction Tank sizing

The definition for *Design Flow* can be found in the tool tip for this section. Click on the information icon ( ) on the right side of the Water Quality and Flow subheading.

3.2.2 Round Baffled Reaction Tank Design:

This section allows the user to select the type of tank construction material. Three material options are available: Fiberglass, Concrete or Steel. Tank volumes options are also specified by the program. For fiberglass tanks, the user can select from three optional volume selections: 10,000-gallon, 20,000-gallon or 30,000-gallon. Concrete or steel tank options offer the user a choice of either 30,000-gallon, 60,000-gallon or 90,000-gallon tanks. All available tank size geometries are defined by the AMDTreat program. Tables 1 and 2 listed below, illustrates tank geometry user material and volume selections.

Fiberglass Reaction Tank Geometry

Tank Volume (gal)	**10,000**	**20,000**	**30,000**
Tank Diameter (ft)	12	14	16
Tank Height including freeboard (ft)	14	18	20.5

Table 1: Fiberglass tank dimensions based on available volume selection

Concrete or Steel Reaction Tank Geometry

Tank Volume (gal)	**30,000**	**60,000**	**90,000**
Tank Diameter (ft)	20	28	34
Tank Height including freeboard (ft)	16	16	16

Table 2: Concrete or Steel tank dimensions based on available volume selection

Within this section users can, when choosing a steel tank, select between either bolted or welded fabrication techniques. In addition, the user may choose between protective coatings applied to the tank. If the user selects a Concrete tank the option to include a protective coating suitable for concrete tanks is also available.

3.2.3 Equipment: This section allows users to select optional equipment that is routinely included with Reaction Tanks in mine drainage treatment applications. Mixer type, Variable Frequency Drive Unit (VFD) for the mixer, operational times, various safety/access equipment, and foundation variables can be optionally selected.

3.2.3.1 Mechanical Mixer: If the checkbox for Mechanical Mixer is selected, the user can select between two default mixer types, either a mechanical mixer or surface aerator, AMDTreat program automatically provides horsepower quantities that are based upon the tank volume that the user selected in the previous section. Electrical cost values are entered by the user or the default value is used in the Annual Cost Input section of the module (discussed later below). The user also may select an option that allows for entering custom, or user specified values for mixer horsepower and electrical cost. A Variable Frequency Drive Unit (VFD) for the mixer can be selected to provide for operational control of mixer function to accommodate changes in influent flow and water chemistry and possibly to refine or improve the reaction tank performance and economy. Lastly, operational times in terms of operational hours per day and per year can be adjusted to further refine annual cost estimates. Table 3 below provides the default horsepower rating that AMDTreat automatically selects based on Reaction Tank size selection.

Default Mixer Horsepower (HP) based on selected Reaction Tank Size

Tank Volume (gal)	**10,000**	**20,000**	**30,000**	**60,000**	**90,000**
Surface Aerator	5	10	15	25	40
Mechanical Mixer	5	15	20	40	50

Table 3: AMDTreat default mixer horsepower

3.2.3.2 Safety/access equipment:

Users may specify Catwalks with Handrails and/or Stairs with Handrails for access and safety considerations. Defaults values for these options can be easily adjusted through a wide range of cost values. If the user envisions additional items or has alternative designs for these features, the Other Capital Items Section (discussed below) can be utilized to cost model these items.

3.2.3.3 Foundation: The first step in estimating the capital cost of the foundation for the Reaction Tank Module is to specify, or accept the default, *Concrete and Material Placement* unit cost used to calculate the cost to purchase, deliver, and form (including rebar) the concrete foundation. The second step is to select the site soils load bearing value (i.e. 1500, 3000, or 4500 [lb/ft^3]). AMDTreat estimates the foundation area using the information in Table 4. Foundation thickness depends on soil quality selected and type of tank selected. Fiberglass tanks have a standard foundation thickness of 0.75 feet and Concrete or Steel Tanks have a standard foundation thickness of 3.5 feet. Tank diameter along with soil condition selected determine the foundation area. The user should be aware that mine subsidence concerns are not addressed in the AMDTreat foundation design and that these concerns if applicable need to be addressed separately by the system designers with the appropriate input from qualified Geotechnical Engineers.

For either sizing method, the foundation volume is multiplied by the *Concrete and Material Placement Unit Cost* to estimate the capital cost of the foundation. If no foundation is required, users can make the *Concrete and Material Placement* $0.0 per yd^3.

Fiberglass Tanks

Tank Size (gal)	**Tank Diameter (ft)**	**Foundation thickness (ft)**	**Foundation area (ft)**
10,000	12	0.75	*
20,000	14	0.75	*
30,000	16	0.75	*

Table 4: Foundation design relationship to Tank type, size, and soil conditions for Fiberglass. Tanks. * *Foundation area determine by soils conditions in addition to the above parameters*

Concrete or Steel Tanks

Tank Size (gal)	**Tank Diameter (ft)**	**Foundation thickness (ft)**	**Foundation area (ft)**
30,000	20	3.5	*
60,000	28	3.5	*
90,000	34	3.5	*

Table 5: Foundation design relationship to Tank type, size, and soil conditions for Concrete or Steel Tanks. * *Foundation area determine by soils conditions in addition to the above parameters*

3.2.4 Other Capital Items: The *Other Capital Items* section allows users to capture the capital cost of equipment and other items that are not included in this module. For example, in some cases users may want to include the cost of a pH controller, probe or other monitoring device in the Reaction Tank Module. This can be accounted for here in the *Other Capital Items* section to capture the capital cost.

3.2.5 Annual Cost Items: The *Annual Cost* section allows users to specify unit cost for electricity in $/kWh for the electrical equipment selected for the reaction tank module in the Equipment Section.

3.2.6 Other Annual Items: The *Other Annual Items* section allows users to capture the capital cost of equipment and other items that are not included in this module. For example, users could include the annual subscription cost to conduct electronic surveillance on the treatment system in the *Other Annual Items* section.

3.3 Module Outputs

3.3.1 Sizing Summary: The Sizing Summary section displays important calculated module outputs, such as estimates of retention time, reaction tank sizing and volumetrics, mixer power specifications, land area estimates and foundation requirements.

3.3.2 Capital Cost: This section provides the estimated costs for the various user-specified components and the total estimated cost to construct the Reaction Tank component of the treatment system. Users can opt to estimate the installation cost by specifying it as a percentage of the capital cost or by entering a cost. Likewise, users can have the program estimate the capital cost of the Reaction Tank or specify the cost.

3.3.3 Annual Cost: The annual cost section provides an estimate of the annual cost, primarily electrical cost, to operate and maintain the Reaction Tank component treatment system. Users can select to have AMDTreat estimate the annual cost or specify an annual cost. Specifying an annual cost is often used when AMDTreat's Net Present Value calculations are being used to estimate water treatment liability. The annual maintenance for the Reaction Tank treatment system component can either be specified by the user or estimated by assuming it is a percentage of the capital cost. The latter method assumes the more expensive systems are more costly to maintain.

3.3.4 Net Present Value: The Net Present Value (NPV) section determines the cost to operate a treatment system component over a specified time period. The NPV calculates the present-day financial investment required to generate the income to pay for future operation and equipment/materials replacement costs. Both **Financial Variables** and **Cost Categories** are required to calculate the NPV.

> *3.3.4.1 Financial Variables* - The *Term of Analysis*, *Inflation Rate*, and *Rate of Return* are three variables used in the NPV calculations. The default values for these terms are shown under the *Net Present Value* section of each module. Users must access the *Net Present Value* menu at the top of the main user interface to change the default values as they would apply to all modules used for an entire treatment system. While NPV is determined for each AMDTreat module activated by the user, the goal is to determine a total NPV for an entire mine drainage treatment system project (a collection of cost estimates for individual modules creates a treatment system project in AMDTreat). Therefore, a single value for *Term of Analysis*, *Rate of Return*, and *Inflation Rate* is applied to all modules and cannot vary between modules.

- Term of Analysis: The time period used by the NPV calculation to determine the financial investment required to pay for all future costs of the treatment system.

- Inflation Rate: Represents the average price increase of goods and services over time. AMDTreat uses the inflation rate to calculate the future cost of the annual operation and maintenance (O&M) and recapitalization items.

- Rate of Return: Describes the expected profit on an investment.

3.3.4.2 Cost Categories - For each treatment module, AMDTreat provides a list of recommended equipment and materials that require recapitalization. In addition, AMDTreat provides recommendations (default values) for life cycle and replacement percentage. Users can click on the default values for *Life Cycle* or *Replacement Percentage* and use the +/- buttons to change the default values. In addition, users can select *Custom Cost* and enter a new cost to represent the current cost of the equipment. Users can add new recapitalization items or deactivate/delete existing items for calculating the NPV.

An example of how the recapitalization variables are used to determine NPV is to consider the following hypothetical scenario. Assume a vertical turbine pump has a life cycle of 50 years but requires the pump motor to be rebuilt every 20 years. Assume the present-day cost to purchase the motor is $500,000, and the cost to remove, rebuild, and reinstall the pump motor is $20,000. Now assume we want to determine the amount of investment required today (NPV) to generate the income to pay for the future cost of rebuilding the pump motor over a 50-year *Term of Analysis*, which is also equal to the life cycle of the pump. Assume an *Inflation Rate* of 5.0% and *Rate of Return* of 8.1%. The goal is to place the money in a relatively secure investment vehicle to generate 8.1% annually. The NPV will calculate the size of investment required to generate income for future costs.

There are several ways to model the replacement cost. One way is to replace 4% of the present-day cost of the pump (4% of $500,000 = $20,000) with a life cycle of every 20 years. If the *Term of Analysis* is 50 years, then the entire pump would not require recapitalization since the life cycle of the pump is 50 years. However, the motor would require two replacements (50 years / 20 years = 2.5 rounded down to 2).

To determine the NPV to recapitalize the rebuilding of the motor, AMDTreat calculates the future cost to rebuild the motor at each life cycle, 20 and 40 years. The program uses the *Inflation Rate* to inflate the present-day default cost to rebuild the motor in 20 and 40 years from now. While the present-day cost to rebuild the pump motor is $20,000, the future cost to rebuild the motor in 20 years at a 5.0% *Inflation Rate* is $53,065 (Equation 1). Assuming an 8.1% *Rate of Return*, the 50-year NPV for the pump is $17,422. In other words, an initial investment of $17,422 is needed at an annual *Rate of Return* of 8.1% to generate the investment income required for the two motor rebuilds over the 50-year life cycle of the pump.

Cost to rebuild pump motor in 20 years =

$$Present\ Day\ Cost\ \times (100\% + Inflation\ Rate)^{20} = \$20{,}000 \times (100\% + 5\%)^{20} = \$53{,}065$$

- Annual Operation and Maintenance Cost: By default, AMDTreat transcribes the annual O&M cost from the Annual Cost section to the Net Present Value section. The program assumes the module is being used to first estimate the annual cost for a treatment system component, so it automatically transcribes the annual cost to the NPV section. If this is not the case or the user wants to use some other annual cost, the “Use Custom” box can be selected to allow the user input of a different annual cost to utilize in the NPV calculation.

- Recapitalization Cost: Certain treatment system components, especially mechanical and water conveyance equipment, require periodic replacement. The recapitalization cost of an item is an estimate of the amount of money required to pay for future replacement costs for the item. In addition to the Financial Variables described above, three additional values are required to calculate the NPV of recapitalization costs, the Present-Day Equipment Cost, the Life Cycle, and the Replacement Percentage.

- Default Cost: This represents the current cost to purchase the equipment or material.

- Life Cycle: The time frame between equipment or material replacement is termed as its Life Cycle. Some equipment manufacturers provide recommended life cycles for their equipment to provide consumers with an estimate of how long the equipment is expected to be operational. Some life cycles, such as those used for treatment media (limestone), are based on best professional judgement. Some operators prefer to periodically purchase and replace equipment before failure to preserve the continuity of operations, while others wait until failure to replace an item.

- Replacement Percentage: The Replacement Percentage is an adjustment factor to the Default Cost to accommodate situations where the entire piece of equipment or all of the material does not require recapitalization. For example, a passive treatment component may be designed to contain enough limestone to neutralize the acidity load for 20 years, however, the accumulation of metal hydroxide precipitates within the void space of the limestone layer may require that 25% of the limestone be replaced every 7 years to prevent hydraulic failure such as plugging or short-circuiting. For this scenario, the initial cost of the limestone making up the limestone layer is discounted by 75% and assigned a life cycle of 7 years to determine the amount of money required to cover the cost of replacing 25% of the limestone layer every 7 years over the Term of Analysis.

3.3.4.3 Rationale for Recapitalization Recommendations:

Recapitalization recommendations are based on professional experience of the AMDTreat Team and may not apply to all situations. Users are encouraged to customize the recapitalization assumptions to their treatment scenario. AMDTeat Team members are located in Pennsylvania and West Virginia and have collective experience in design, funding, and/or operation/maintenance for over 100 passive treatment systems. The AMDTreat Team held discussions on personal experience to develop a list of recapitalization recommendations. Users may have different experience and opinions than those listed.

By default, AMDTreat includes a list of eight recapitalization items the Reaction Tank. Users can delete or modify any of the default Recapitalization items by either deselecting the item or by setting the Replacement % to zero. If the item is deselected the Total Cost for the item will still be shown but the cost will be subtracted from the Net Present Value Cost, shown in the Net Present Value Heading. Users are free to fully customize the replacement items, including adding new items or deleting default items.

The Life Cycle of a Steel Reaction Tank depends on how well the bottom of the tank is protected from ground moisture, how often it is sandblasted and painted, and whether the tank is vandalized. After considering the condition and life of many steel tanks, the AMDTreat team feels 30 years is a good estimate as long as the tank is on a concrete or gravel foundation or on wooden cribbing to prevent contact with ground moisture. A much longer Life Cycle may be appropriate if the tank is cleaned, primed, and painted when corrosion becomes visible. Concrete Reaction Tank Life Cycle is defaulted to 75 years based upon observations of existing systems that AMDTreat members have observed.

3.4 Assumptions of Design Sizing and Costs

AMDTreat is a cost estimation model that uses assumptions to provide treatment sizing and both capital and annual cost estimates. While there are many assumptions in the program, the assumptions that follow are important for the Reaction Tank module.

1. A round baffled tank design that models a Continuous Stirred Tank Reactor (CSTR) is the only type of Reaction Tank modeled in AMDTreat. Plug Flow Reactor (PFR) and Complete Mix Batch Reactors (CMBR) are not currently included in the program.
2. The CSTR reactor in the program is considered to be an "ideal" mixer, meaning that no short-circuiting of flow paths or "dead spots" exist within the tank. Consequently, users and system designers should make allowances and apply design safety factors to account for real world inefficiencies.
3. The current program allows for a finite number of choices for Reaction Tank sizing that correspond to a limited number of tank materials. Fiberglass tanks of either 10,000, 20,000 or 30,000 gallons can be selected. Steel or concrete tank volumes of 30,000, 60,000, or 90,000-gallon tanks can be utilized.
4. Gas exchange (aeration and/or decarbonation) design is not considered in the Reaction Tank Module. Other AMDTreat modules can be utilized to evaluate these treatment system considerations.

4.0 References

Types of Reactors - Chemical Engineering World

5.0 Figures

Figure 1: Steel CSTR Round Baffled Reaction Tank with a mechanical mixer.

Figure 2: Concrete Reaction Tank showing baffles and mechanical mixer impeller. This is a western US hard rock mine site (Butte, Montana) Note - Calcite and Gypsum scaling issues.

Figure 3: Photo of calcite and gypsum scale that can develop in highly mineralized mine water. Annual O&M cost calculations must account for this situation.

Figure 4: Photo of a large concrete CSTR Reaction Tank with fully grated top surface in lieu of a catwalk. Mechanical mixer (100HP) is centrally mounted on structural steel support members.

Figure 5: Surface Aerator in a large concrete CSTR Reaction Tank.

Figure 6: Mechanical mixer in a welded steel CSTR Reaction Tank.