Mazzei Wastewater Aeration System
SOTR Test Results

Introduction:

The Mazzei wastewater aeration system has been exhaustively tested following the **American Society of Civil Engineers (ASCE) Measurement of Oxygen Transfer in Clean Water, ANSI/ASCE 2-91 Second Edition[1].** The testing has been witnessed and certified by a Professional Engineer.

What is the Mazzei Wastewater Aeration System?

Mazzei's aeration system is composed of three basic units:

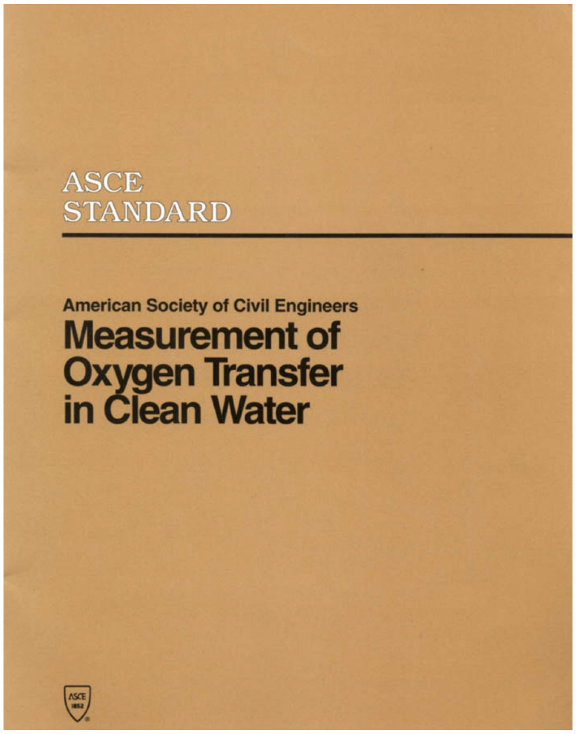
1: Circulation Pump
2: Mazzei® Venturi Injector(s)
3: Mass Transfer Multiplier™ (MTM) Nozzles

The circulation pump circulates water from the aeration basin through the Mazzei venturi injector(s) which aspirate large volumes of air, or concentrated oxygen, without the need for blowers or compressors. The MTM nozzles discharge the air/water mixture from the Mazzei venturi injector into the bottom of the aeration basin at a designed velocity of about 15 ft/s, effectively mixing the aspirated air with several volumes of water in the aeration basin.

The result is quiet, efficient oxygen transfer without water depth limitations.

What is SOTR?

SOTR is the **Standard Oxygen Transfer Rate** of an aeration system determined by measurement of non-steady-state oxygen uptake in clean water, which is measured following the test protocol detailed in the **American Society of Civil Engineers (ASCE) Measurement of Oxygen Transfer in Clean Water, ANSI/ASCE 2-91 Second Edition[1].**



SOTR is expressed in units of #/hour of oxygen transferred into clean water under standard conditions, which are defined as:

20° C Water Temperature
1.0 Standard Atmosphere Pressure
0 mg/l Dissolved Oxygen

Why is SOTR Important?

The SOTR of an aeration system is the design basis for matching the oxygen transfer capability to the oxygen requirement of a wastewater treatment facility. Without accurate and reliable **SOTR** data, ***the specification of an aeration system for a wastewater treatment facility becomes little more than a guessing game.***

How is SOTR Used?

The **SOTR** is corrected to the **Operating Oxygen Transfer Rate (OTR)** under the actual operating conditions of a wastewater treatment facility following the procedures detailed in the **Water Environment Federation (WEF) Manual of Practice (MOP) FD-13**[2]. Following is the formula used for correction of the **SOTR** to the **OTR**.

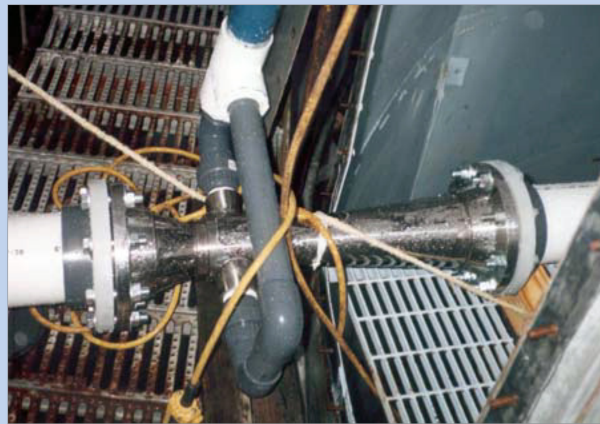
$$\mathbf{OTR} = ((\alpha\ (\mathbf{SOTR})\theta)/\ C^*_{\infty 20}\ )\ x\ ((\ \tau\ \Omega\ \beta\ C^*_{\infty 20}\ \ )\ -\ C_{op}\ )$$

This formula accounts for the affects of water temperature, operating dissolved oxygen (DO), water chemistry, etc., in the calculation of the **OTR**. A detailed discussion of the factors employed in this formula is presented in a later section.

SOTR Testing Facilities

Following are pictures of the test facilities and components employed during the tests.

Test tank 21' diameter x 30' deep and a circulation pump



Mazzei Model 6094 venturi injector

Mazzei N45 nozzles and manifold

Mazzei N45 nozzles and manifold

Dissolved oxygen meters

Data Analysis Computer

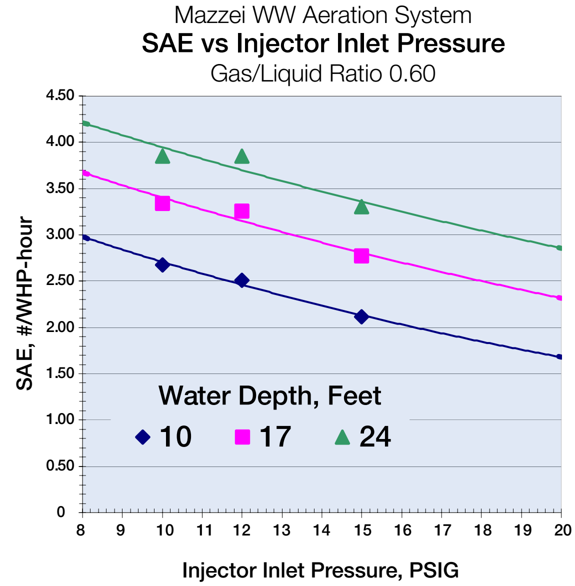


CHART 1: SAE vs Injector Inlet Pressure

The **SAE** of the Mazzei wastewater aeration system increases with decreasing injector operating pressure.

Operating Variables

Forty-one non-steady-state oxygen uptake tests were performed to determine the **Standard Oxygen Transfer Rate (SOTR)** for the Mazzei aeration system relative to the following variables:

1. **Injector Inlet Pressure**
2. **Water Depth**
3. **Gas/Liquid Ratio, Vg/Vl**

Results

Oxygen transfer test results are expressed in units of **Standard Oxygen Transfer Rate (SOTR)**, or **Standard Aerator Efficiency (SAE)**. **Standard conditions** are, by definition, **1.0 standard atmosphere** absolute pressure (14.694 PSIA), **20.0° C** water temperature, and **0 mg/l dissolved oxygen** concentration. **SOTR** is expressed in units of #/hour of oxygen transferred. **SAE** is in units of #/WHP-hour (#'s O_2 transferred per water horsepower hour applied). **SAE** relative to brake horsepower is dependent on the pumps, motors etc., employed in a Mazzei aeration system and is calculated during system design. ***The following CHARTS are summaries of the test results, and are not intended for system design.*** A much more detailed compilation of the **SOTR** results is used for actual system design/specification.

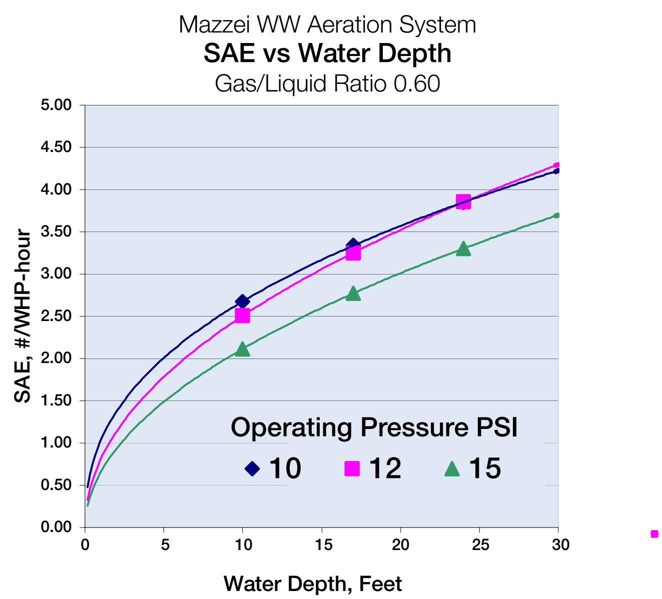


CHART 2: SAE vs Water Depth

The **SAE** of the Mazzei wastewater aeration system with increasing water depth.

CHARTS 3, 4, and 5: The **SAE** of the Mazzei wastewater aeration system increases with increasing gas/liquid ratio, Vg/Vl. The gas/liquid ratio is the volumetric ratio of the amount of air relative to the circulation rate through the aeration system. Units are SCFM air or oxygen and CFM circulated water.

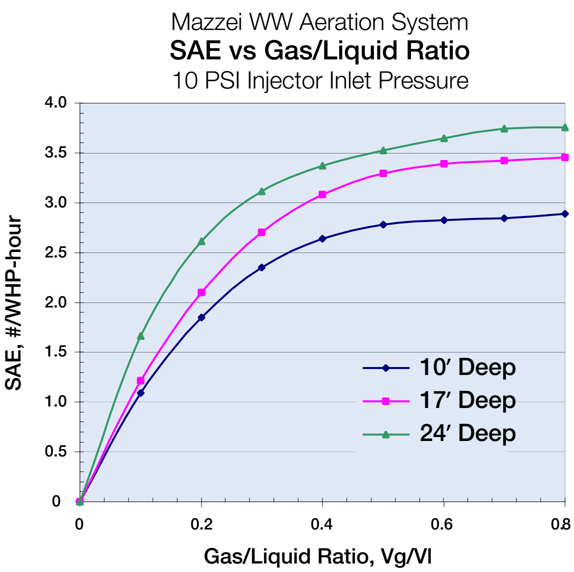


CHART 3: SAE vs Gas/Liquid Ratio @ 10 PSI

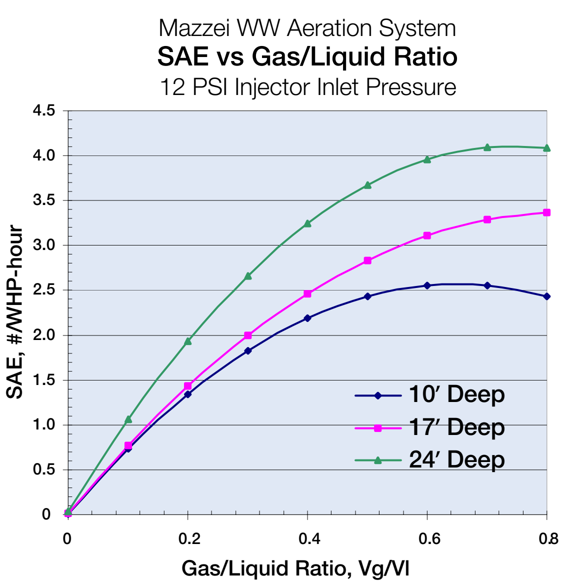


CHART 4: SAE vs Gas/Liquid Ratio @ 12 PSI

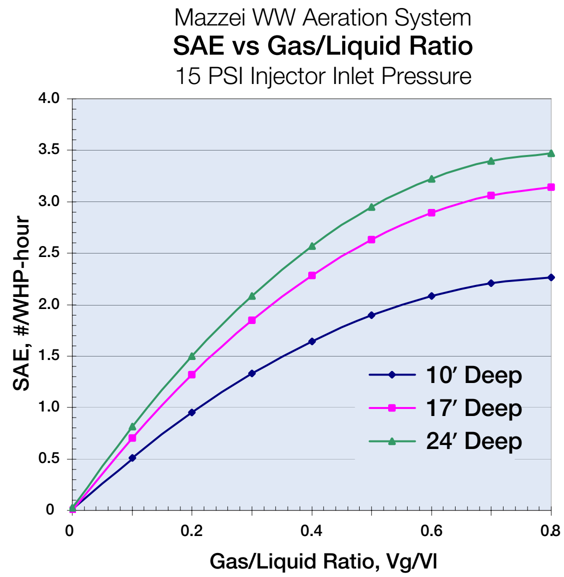


CHART 5: SAE vs Gas/Liquid Ratio @ 15 PSI

Aeration System Design

Oxygen Requirement:

The oxygen requirement for an activated sludge wastewater treatment system is estimated following the calculation procedures articulated in **Wastewater Engineering, Treatment, Disposal & Reuse, Third Edition Metcalf & Eddy**[3]. These calculation procedures have been compiled into an Excel based spreadsheet that facilitates rapid estimation of the oxygen requirement for an activated sludge system. **TABLE 1** is an example of this spreadsheet.

System Design:

The circulation rate necessary to meet the oxygen delivery requirement is the primary factor that must be determined in the process of designing a Mazzei wastewater aeration system. In order to expedite the calculation of the circulation rate necessary to meet the oxygen requirement, the **SOTR** data has been processed and compiled into a set of formulas that account for the affect of both gas/liquid ratio and water depth on the **SOTR**. The **SOTR** for the gas/liquid ratio and water depth of the proposed system/facility is then corrected to the **OTR** using the following formula[2]:

$$\mathbf{OTR} = ((\alpha\,(\mathbf{SOTR})\,\theta)/\,C^*_{\infty 20})\ \mathrm{x}\ ((\tau\,\Omega\,\beta\,C^*_{\infty 20}) - C_{op})$$

and

$$\mathbf{C^*_{\infty T}} = \tau\,\Omega\,\beta\,\mathbf{C^*_{\infty 20}}$$

Where the following definitions apply:

$\mathbf{C^*_{\infty 20}}$ **=** Standard Conditions Saturation **DO**

$\mathbf{C^*_{\infty T}}$ **=** Operating Conditions Saturation **DO**

$\mathbf{C_{op}}$ **=** Operating **DO**

It can be seen that the **OTR** is affected by the saturation **DO** ($\mathbf{C^*_{\infty T}}$) and operating **DO** ($\mathbf{C_{op}}$). The operating **DO** ($\mathbf{C_{op}}$) is dictated by the system requirements, typically about 2.0 mg/l for activated sludge systems.

The factors that affect the saturation solubility of oxygen in water are defined as follows[2]:

Tau (τ) = $\mathbf{C^*_{\infty T} / C^*_{\infty 20}}$

Omega (Ω) = Saturation **DO** at Operating Pressure Relative to Standard Pressure

Beta (β) = The effect of water chemistry on Saturation **DO**

The effect of water temperature, **Tau (τ)** factor, on saturation **DO** concentration is well documented, and these values are available from numerous sources.

The **OTR** under operating conditions in dirty water is also affected by factors expressed as the **Alpha (α)** and **Theta (θ)** factors. The **Alpha (α)** and **Theta (θ)** factors affect the mass transfer rate coefficient, $\mathbf{K_La}$, and they are defined as follows[2]:

Alpha (α) = Dirty Water/Clean Water $\mathbf{K_La}$

Theta (θ) = Operating/Standard Temp $\mathbf{K_La}$

The mass transfer rate coefficient ($\mathbf{K_La}$) is a function of the diffusion rate of oxygen across the air/water interface. Chemicals such as detergents in process water can have a substantial affect on the $\mathbf{K_La}$. In passive, diffusion type aeration systems, such as coarse bubble diffusion, the **Alpha (α)** factor can range from 0.2–0.8[1]. Simulated dirty water testing by addition of common detergents, as well as field results, indicates that the **Alpha (α)** factor for the Mazzei wastewater aeration system is approximately 1.0 due to dynamic agitation. **Theta (θ)** is assumed to be 1.024 for most wastewater aeration systems unless empirical data suggest otherwise[2].

TABLE 2 is an example of the Excel based spreadsheet used to calculate the required circulation rate for the oxygen requirement of the facility. In addition to circulation rate, horsepower requirements and **operating aeration efficiency** are also calculated.

Bibliography

1: American Society of Civil Engineers (ASCE) Measurement of Oxygen Transfer in Clean Water, ANSI/ASCE 2-91 Second Edition

2: Water Environment Federation (WEF) Manual of Practice (MOP), FD-13 Copyright 1988

3: Wastewater Engineering, Treatment, Disposal & Reuse, Third Edition, Metcalf & Eddy Copyright 1991

Mazzei Injector Company Wastewater Aeration System

Oxygen Demand Calculation

Prepared for:
Project:
Purpose for Aeration:
Date: 3/5/2002

TABLE 1

Example Oxygen Requirement Calculation

FLOW RATES & LOADING	UNITS	VALUE	COMMENTS
Average Design Flow, **ADF**	MGD	1	
Influent Loading **@ ADF**:			
BOD5	mg/l	200	
TKN	mg/l	40	
Effluent Loading:			
BOD5	mg/l	10	
TKN	mg/l	1	
DESIGN PARAMETERS			
Aeration Basin Volume	Gallons	400,000	
Hydraulic Retention Time (**HRT**)	Days	0.4	at **ADF**
Mixed Liquor Volatile Suspended Solids	mg/l	1,700	Assumed
Sludge Yield, Y, #VSS/#BOD5	**#/#**	**0.7**	**Assumed**
Specific Decay Rate, **Kd**	#/day	0.02	Assumed
Design MCRT (Sludge Age)	**Days**	**5.7**	
Yobserved (Yobs) #VSS/#BOD5	**#/#**	**0.63**	
Food/Microorganism Ratio	**#/#**	**0.294**	
Px, Net Waste Sludge, **@ ADF**	#/day	996	
Calculated MCRT @ ADF Load	**Days**	**5.7**	
BOD5 to BOD Ultimate Factor		0.71	Generally 0.46–0.71; 0.71 Assumed
Denitrification Credit Claimed?	NO	4.57	If NO, enter 4.57; If YES, enter 1.71
OXYGEN REQUIREMENT CALCULATIONS			
Carbonaceous O_2 Demand **@ ADF**	#/day	818	
Nitrification O_2 Demand **@ ADF**	#/day	1,486	
Total O_2 Demand **@ ADF**	#/day	2,304	
Available Aeration Time	hr/day	24	
O_2 Delivery Requirement **@ ADF**	#/hr	96.02	Prorated for available aeration time
O_2 Uptake Rate (**OUR**) **@ ADF**	mg/lhr	28.8	

REFERENCE: Wastewater Engineering, Metcalf & Eddy, Third Edition

Mazzei Injector Company Wastewater Aeration System

Oxygen Transfer Rate and System Design Calculation

Prepared for:
Project:

TABLE 2

Example Oxygen Requirement Calculation

	UNITS	VALUE	COMMENTS
Available Aeration Time	hr/day	24	
O_2 Delivery Requirement @ **ADF**	#/hr	96.0	Prorated for available aeration time
AERATION BASIN OPERATING CONDITIONS			
Water Depth (min entry is 5 ft)	**ft**	**30**	
Water Temperature	**C**	**20**	Assumed
Operating Dissolved Oxygen	**mg/l**	**2.0**	Assumed
AERATION SYSTEM OPERATING CONDITIONS			
Injector Operating Pressure	**PSI**	**15**	**10, 12, or 15 PSI**
Gas/Liquid Ratio	**Vg/Vl**	**0.70**	**SCFM Air/CFM of water circulated**
SOTR @ Operating Pressure/Depth	#'s/hr	**3.34**	#'s O_2 transferred/hr PER 100 GPM circulated
Standard Aerator Efficiency (**SAE**)	#'s/WHP-hr	**3.82**	@ 0 mg/l DO, 20º C, 1.0 ATM(A) Press, 100% pump efficiency
DO Saturation Conc. @ 20º C	mg/l	9.09	Assumed, from tables
DO Saturation Conc. @ Op. Temp	mg/l	9.09	From tables
Tau (τ)		1.00	Sat DO @ OP. temp/sat DO @ 20º C
Theta (θ)		1.024	Assumed
Beta (β)		1.00	Assumed
Omega (Ω)		1.00	Assumed
Alpha (α)		1.00	Assumed
OTR @ Operating Temp and **DO**	#'s/hr	2.67	#'s O_2 transferred/hour PER 100 GPM circulated
AERATION SYSTEM OPERATING PARAMETERS			
Required Circulation Rate	GPM	3,599	For the O_2 delivery requirement @ **ADF**
Injector Model and Number of Injectors	**12050**	**2**	
Circulation Rate	GPM	4,943	
Actual Oxygen Transfer Rate	#'s/hr	131.89	
Excess Oxygen Transfer Capability	#'s/hr	35.87	
Injector Level Above Water	ft	2.0	
Water Horsepower Requirement	WHP	45.75	
Pump Efficiency	**%**	**79**	
Brake Horsepower Requirement	BHP	57.91	
Aerator Efficiency	#'s/BHP-hr	2.28	Based on maximum delivery capability

REFERENCES:

- Wastewater Engineering, Metcalf & Eddy, Third Edition
- Water Pollution Control Federation, Manual of Practice FD-13
- American Society of Civil Engineers (ASCE): Measurement of O_2 Transfer in Clean Water, 2nd Edition