Mazzei AirJection® System SOTR Test Results

Introduction:

The Mazzei AirJection® System for wastewater aeration 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 AirJection® System?

The AirJection® System is composed of three basic units:

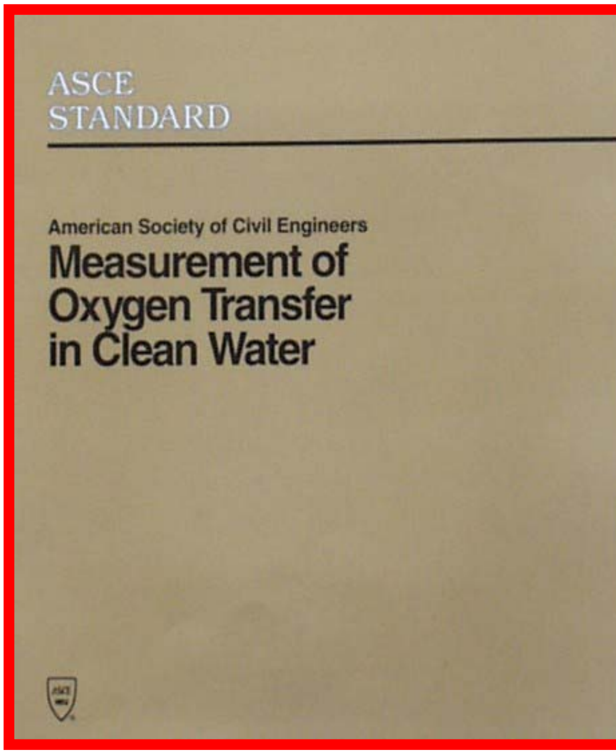
1: Circulation Pump
2: High Efficiency Venturi Injector(s)
3: Mass Transfer Multiplier Nozzles

The circulation pump circulates water from the aeration basin through the High Efficiency venturi Injector(s) which aspirate large volumes of air, or concentrated oxygen, without the need for blowers or compressors. The Mass Transfer Multiplier Nozzles discharge the air/water mixture from the High Efficiency 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 with out 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.

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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 **WEF Manual of Practice, MOP, FD-13**[2]. Following is the formula used for correction of the **SOTR** to the **OTR**.

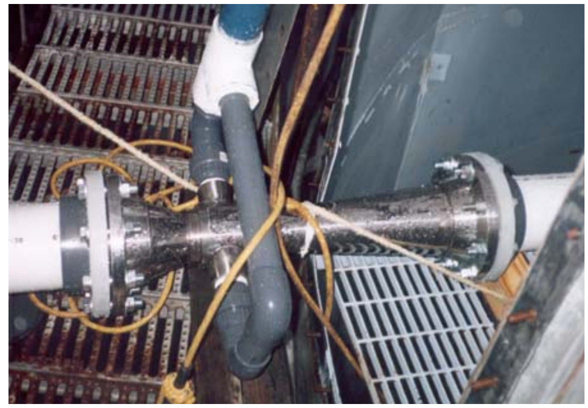
$$OTR = ((\alpha\ (SOTR)\ \theta)/\ C^*_{\infty 20}\ )\ x\ ((\ \tau\ \Omega\ \beta\ C^*_{\infty 20}\ )\ -\ C_{op}\ )$$

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 & Circulation Pump



Mazzei Model 6094 Venturi Injector

Mazzei N45 Nozzles & Manifold

Dissolved Oxygen Meters

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Data Analysis Computer

Operating Variables:

Forty One Non-Steady State Oxygen Uptake tests were performed to determine the **Standard Oxygen Transfer Rate** (**SOTR**) for the AirJection® 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 O2 transferred per Water-Horsepower hour applied). **SAE** relative to Brake Horsepower is dependent on the pumps; motors etc. employed in an AirJection® System and is calculated during system design. **The following Charts are summaries of the test results, & are not intended for system design.** A much more detailed compilation of the **SOTR** results is used for actual system design/specification.

Chart 1: The **SAE** of the AirJection® System increases with decreasing injector operating pressure.

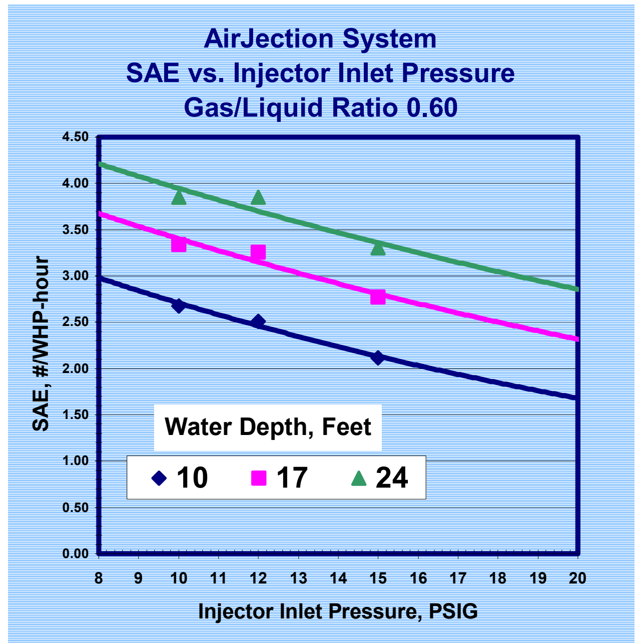

Chart 1: SAE vs. Water Depth

Chart 2: The **SAE** of the AirJection® System increases with increasing water depth.

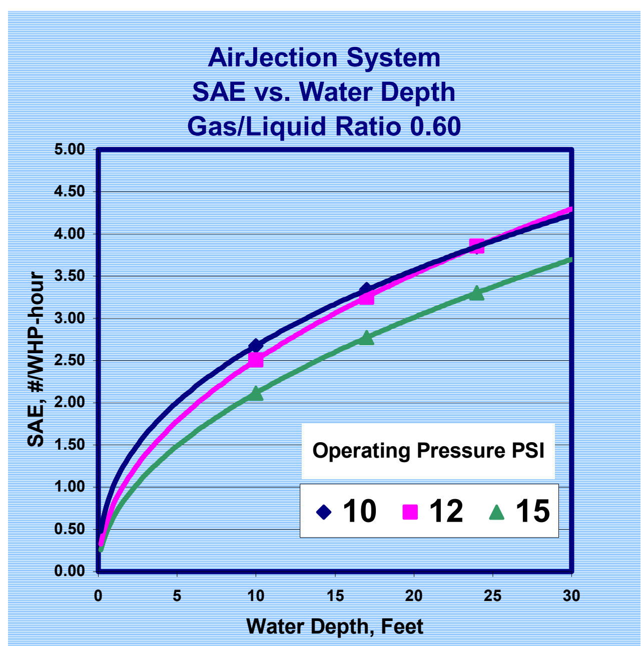

Chart 2: SAE vs. Water Depth

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Charts 3, 4 & 5: The **SAE** of the AirJection® 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 AirJection® System. Units are SCFM air or oxygen and CFM circulated water.

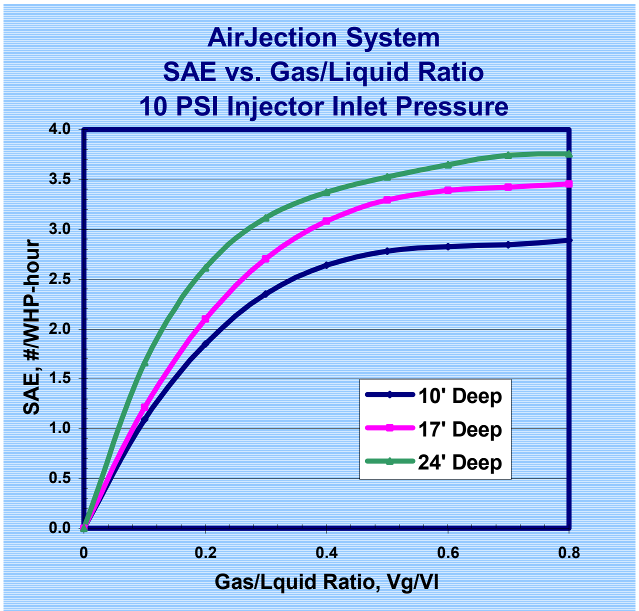

Chart 3: SAE vs. Gas/Liquid Ratio @ 10 PSI

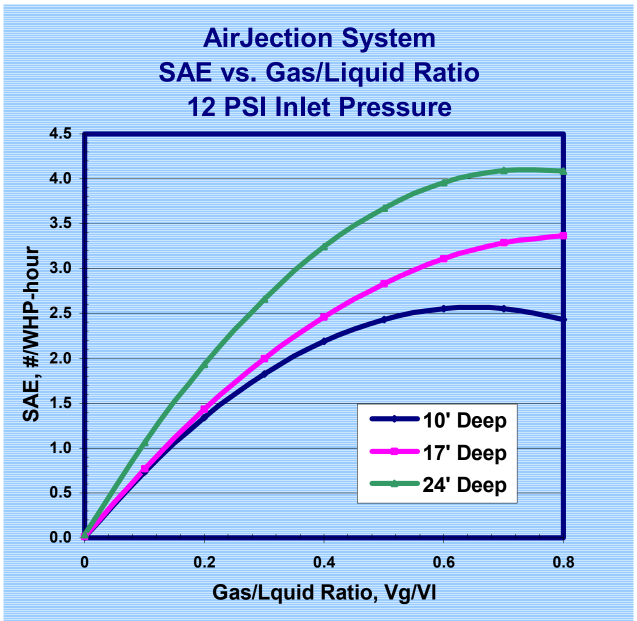

Chart 4: SAE vs. Gas/Liquid Ratio @ 12 PSI

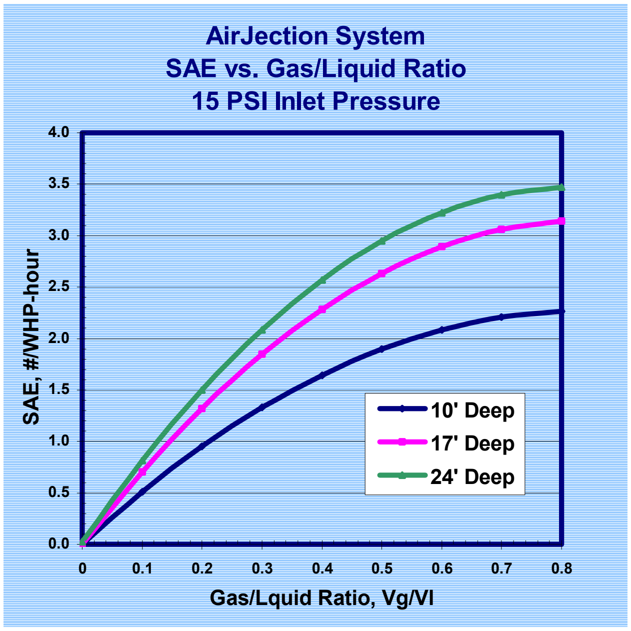

Chart 5: SAE vs. Gas/Liquid Ratio @ 15 PSI

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 and 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 an AirJection® 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

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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]:

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

And

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

Where the following definitions apply:

$C^*_{\infty 20}$ = Standard Conditions Saturation **DO**
$C^*_{\infty T}$ = Operating Conditions Saturation **DO**
C_{op} = Operating **DO**

It can be seen that the **OTR** is affected by the saturation **DO, $C^*_{\infty T}$,** and operating **DO**, **C_{op}**. The operating **DO, 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) = $C^*_{\infty T}$/ $C^*_{\infty 20}$

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, **K_La**, and they are defined as follows[2]:

Alpha (α) = Dirty Water/Clean Water **K_La**
Theta (θ) = Operating/Standard temp **K_La**

The mass transfer rate coefficient, **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 **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 AirJection™ 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, Manual of Practice, MOP, FD-13 Copyright 1988

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

Mazzei AirJection® System SOTR Test Results

Mazzei Injector Corporation AirJection System
Oxygen Demand Calculation

Prepared For: **Project:** **Purpose For Aeration:** **Date: 3/5/02**	**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	400000	
Hydraulic Retention Time, **HRT**	Days	0.4	At **ADF**
Mixed Liquor VolatileSuspended Solids	mg/l	1700	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 O2 Demand @ **ADF**	#/day	818	
Nitrification O2 Demand @ **ADF**	#/day	1486	
Total O2 Demand @ **ADF**	#/day	2304	
Available Aeration Time	hr/day	24	
O2 Delivery Requirement @ **ADF**	#/hr	96.02	Prorated For Available Aeration Time
O2 Uptake Rate (**OUR**) @ **ADF**	mg/lhr	28.8	

Reference: Wastewater Engineering, Metcalf & Eddy, Third Edition

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Mazzei Injector Corporation AirJection System Oxygen Transfer Rate & System Design Calculation			
Prepared For:	**Table 2**		
Project:	**Example Oxygen Requirement Calculation**		
Available Aeration Time	hr/day	24	
O2 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/hour	**3.34**	#'s O2 Transferred/hour PER 100 GPM Circulated
Standard Aerator Efficiency, **SAE**	#'s/WHPhr	**3.82**	@ 0 mg/l DO, 20 C, 1.0 ATM(A) Press, 100% Pump Efficiency
DO Saturation Conc. @ 20C	mg/l	9.09	Assumed, From Tables
DO Saturation Conc. @ Op. Temp	mg/l	9.09	From Tables
Tau,		1.00	Sat DO @ OP. Temp/ Sat DO @ 20 C
Theta		1.024	Assumed
Beta		1.00	Assumed
Omega		1.00	Assumed
Alpha		1.00	Assumed
OTR @ Operating Temp & **DO**	#'s/hour	2.67	#'s O2 Transferred/hour PER 100 GPM Circulated
Aeration System Operating Parameters			
Required Circulation Rate	GPM	3599	For the O2 Delivery Requirement @ **ADF**
Injector Model & Number Of Injectors	12050	2	
Circulation Rate	GPM	4943	
Actual Oxygen Transfer Rate	#'s/hour	131.89	
Excess Oxygen Transfer Capability	#'s/hour	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/BHPhr	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 O2 Transfer In Clean Water, 2d Edition			

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