Clean Water Oxygen Transfer
清 水 氧 转 移

$$N\,(kg\,O_2\,/\,time) = K_L a(C_S - C)V$$

$K_L a$ = mass transfer coefficient 质量交换系数

C_S-C=driving force. 动力

C=0 mg/l at std conditions 标准状态下为 0mg/l

Aeration Design Considerations
曝气设计需要考虑的事项

$$SOTR = \frac{AOR}{FCF}$$

SOTR – Standard oxygen transfer rate, kg/day
标准氧气转移率, kg/day

AOR – Oxygen demand in process water, kg/day
工艺水的需氧量, kg/day

FCF – Field correction factor
现场修正系数

Aerator Field Correction Factor
曝气现场修正系数

$$FCF = \alpha\text{-}\frac{[(\beta)(ACF)(SCF)(C_{SW} - C)]}{(C_{SS})(SCF)}\text{-}1.024^{(T-20)}$$

Alpha * $\alpha = K_L a_{(field)} / K_L a_{(standard)}$

Beta $\beta = C_{S\,(field)} / C_{S\,(standard)}$

Theta

temperature

elevation

dissolved oxygen concentration*

diffuser submergence

* most important factors最重要因素

Alpha Depends On: 以下因素决定 Alpha

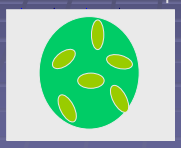
Type of aeration reactor

- 曝气反应器的类型
- Type of aerator
- 曝气机的类型
- Location in aeration system
- 曝气装置的位置
- Wastewater characteristics
- 污水的水质

VertiCel O_2 Transfer Efficiency

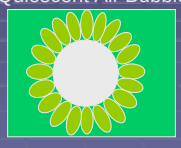
- Raw wastewater with surfactants has higher transfer efficiency with mechanical aerators.

Turbulent Water Droplet



Surfactants in suspension

Quiescent Air Bubble



Surfactants act as barrier

Alpha in Plug Flow System
活塞流系统中的 Alpha

Aerator Type	Location Inlet	Outlet
Fine Bubble	0.2 - 0.4	0.6 - 0.8
Coarse Bubble	0.7 - 0.8	0.7 - 0.8
Mechanical	1.0 - 1.2	0.9 - 1.0

Alpha in Complete Mix System
完全混合系统中的 Alpha

Aerator Type	Sludge Age 4 day	10 day	20 day
Fine Bubble	0.4	0.55	0.70
Mechanical	1.2	1.1	1.0

Field Correction Factors曝气现场校正系数

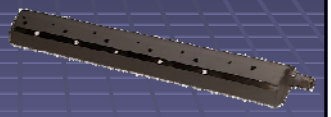
- Biggest factors are alpha and operating DO
  最大的因素为alpha和实际操作中的溶解氧气量
- Alpha - "low" for diffused air device (particularly fine bubble), "high" for mechanical surface aerators.
  Alpha -气扩散曝气设备的Alpha低(尤其是细气泡)，机械曝气设备的Alpha高
  - End result - an "efficient" mechanical aerator can approach (or exceed) fine bubble efficiency in the field - roughly 2.5-3 lb O_2/hp/hr
    最终结果 - 一台"有效"的机械曝气机可以接近（或超过）细气泡曝气功效 – 大概2.5-3 lb O_2/hp/hr
- Staging reactors with low initial DO can provide significant energy benefits (selectors)
  初始溶解氧气量的多级反应器可以提供显著的能量效益（选择器）
- Aerated anoxic zones further enhance staged DO approach
  曝气缺氧区继续增加进程溶解氧气量

Aeration Devices 曝气装置

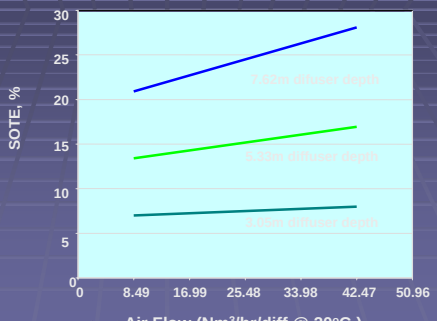
- Diffused Aeration 扩散式曝气
- Mechanical Aeration 机械曝气
- Combination Devices 复合装置

Aeration Devices - Diffused Air
曝气装置-空气扩散曝气

- Diffused Aeration
- 扩散式曝气
  - Coarse Bubble粗气泡曝气设备
    - Snap Caps, Wide Band, Air Band, Discfuser, oth



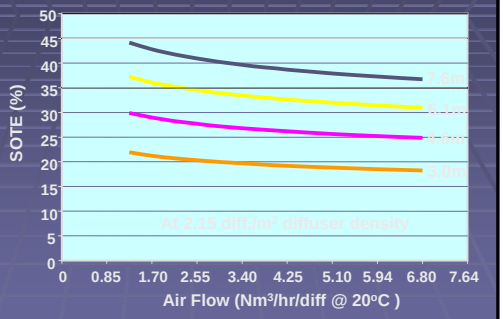

Coarse Bubble Diffuser SOTE
粗气泡曝气管标准氧气的转换效率



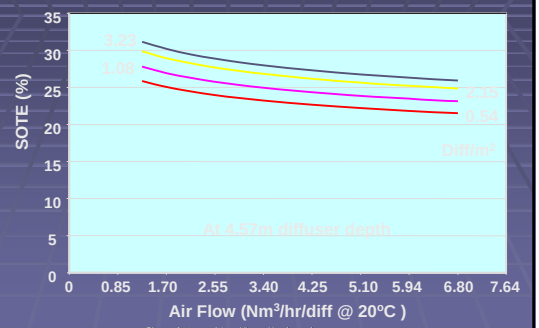
Aeration Devices – Diffused Aeration
曝气装置扩散式曝气

- Diffused Aeration
  扩散式曝气
  - Fine Bubble细气泡曝气设备
    - Ceramic and membrane discs 陶瓷和膜片
    - Ceramic and membrane tubes 陶瓷和膜管
    - Others 其它


Fine Bubble Diffuser SOTE Dependency on Depth
细气泡曝气管标准氧气的转换效率取决于深度



Fine Bubble Diffuser SOTE Dependency on Diffuser Density
细气泡曝气管标准氧气的转换效率也取决于密度



Disk Aerator 转盘曝气机

Aerator Clean Water Transfer
曝气机清水转移

Aerator Type	Comments	SAE kg/kw/hr
Coarse Bubble	Low maintenance. Low oxygen transfer efficiency.	1.2-1.8 kg/kw/hr
Fine Bubble	High clean water transfer efficiency. Potential for fouling, higher maintenance.	3.0-5.5 kg/kw/hr
Low Speed Aerators	Good aeration efficiency, mixing efficiency. Maintenance with gear reducer, aerosols.	1.5-2.1 kg/kw/hr
High Speed Aerators	Low initial cost, flexible operation. Lower aeration efficiency, shallow mixing, aerosols	1.1-1.3 kg/kw/hr

Source: WEF Manual of Practice 8

Aerator Clean Water Transfer
曝气机清水转移

Aerator Type	Comments	SAE lb/hr/hp
Horizontal (brush)	Accessible for maintenance. Good aeration efficiency. Limited tank geometry, aerosols.	1.5-2.1 kg/kw/hr
Horizontal (disc)	Accessible for maintenance. Good aeration and mixing efficiency with less aerosols. Limited tank geometry.	1.5-2.1 kg/kw/hr
Aspirating Aerators	Low cost, flexible. Low transfer efficiency, limited mixing.	0.5-0.8 kg/kw/hr
Jets	Good mixing, high SOTE. Lower SAE, requires pumps and blowers.	2.2-3.5 kg/kw/hr

Source: WEF Manual of Practice 8

应用不同曝气设备组合实现节能示例

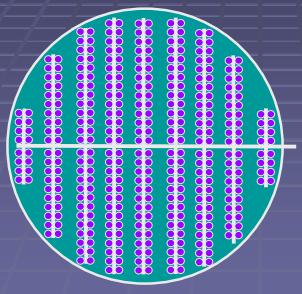
Comparison of Three Aeration Systems

- Flow: 2.16 mgd
- BOD_5: 500 mg/L
- NH_3 - N: 75 mg/L

Design Conditions:

SRT: 20 day
Carb. oxygen demand: 1.25 lb O_2/lb BOD_5
Nit. oxygen demand: 4.6 lb O_2/lb NH_3-N
Denit. credit: 2.3 lb O_2/lb NH_3-N @ 80% denit.

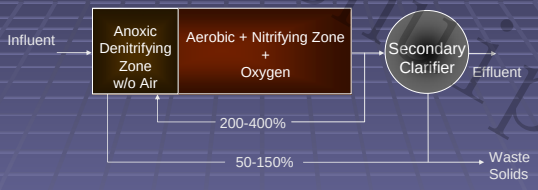
Complete Mix Fine Bubble System



AOR: 728 lb/hr
DO: 2.0 mg/L
Alpha: 0.55
FCF: 0.447
SOTR: 1,629 lb/hr

Power: 262 eHP

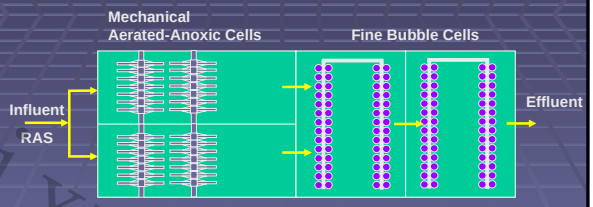
Conventional BNR



AOR*: 600 lb/hr
DO: 0/2.0 mg/L
Alpha: 0.60
FCF: 0.488
SOTR: 1,230 lb/hr

Power: 230 eHP

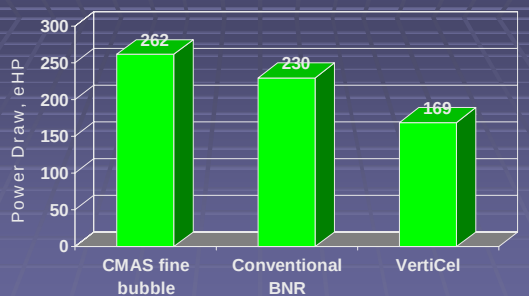
VertiCel Aeration System



AOR*: 600 lb/hr
DO: 0/1.0/2.0 mg/L
Alpha: 0.95/0.66/0.75
FCF: 1.04-0.93/0.63/0.61
SOTR: 806 lb/hr

Power: 169 eHP

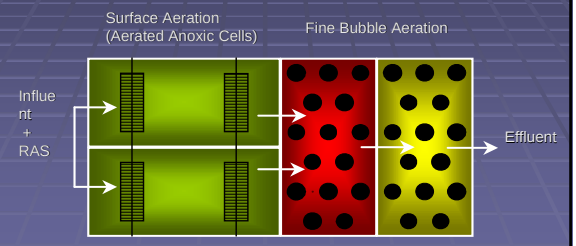
Power draw comparison



Oxygen Delivery Efficiency

	lb AOR/hr/eHp
CMAS Fine Bubble	2.77
Conventional BNR	2.60
VertiCel	3.55

高效-节地-节能的 Verticel活性污泥工艺



主要内容

1、Verticel工艺的由来
2、微生物学原理
3、提高充氧效率、节省曝气能耗的途径
4、应用不同曝气设备组合实现节能--示例

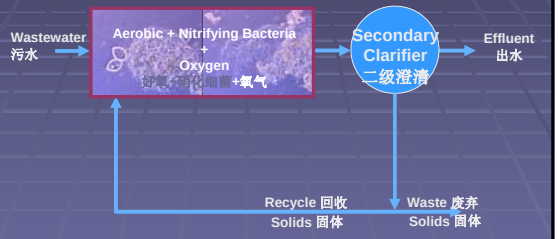
总 体 介 绍

- Verticel活性污泥工艺是在传统污水生物除磷脱氮活性污泥法的基础上演变而来,它的组成类似于orboal 氧化沟工艺。它集成了低溶解氧环境下硝化细菌的高增长性实现短程反硝化。污泥在低溶解氧与高溶解氧的循环下增强了絮凝性,能保持生物反应系统内较高的污泥浓度。同时低溶解氧状态下又有利于提高氧的转移效率。系统中不同充氧设备的有机组合可有效节省充氧的能耗(约20%)。是一种新理念的综合创新。

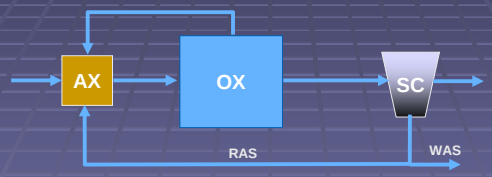
- Verticel工艺实际工程案例的污泥浓度达5 g/l 以上,用于老厂升级改造时通过提高污泥浓度的方式来增加处理能力,具有方法简单、易实施、投资低的特点。同时节能的曝气方式有利于降低运行成本,也符合国家节能减排的大政方针。

Verticel工艺的由来

Basic Activated Sludge Process 基础活性污泥工艺

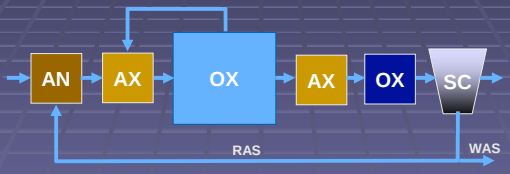


Nitrogen Removal Processes 除氮工艺
Modified Ludzack-Ettinger Process MLE工艺



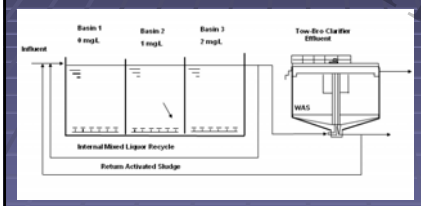
AX = anoxic OX = aerobic SC = Clarifier
AX =缺氧 OX = 好氧 SC = 澄清器

Phosphorus + Nitrogen Removal Processes
Five-Stage BNR Process
磷+氮清除工艺 —5级生化去氮



AN = Anaerobic AX = anoxic OX = aerobic SC = Clarifier
AN = 厌氧 AX = 缺氧 OX =好氧 SC = 澄清器

BIONUTRE® Process



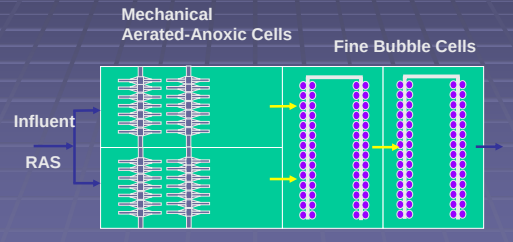
Orbal BNR 脫氮旁路捷徑

- $NH_4 \rightarrow NO_2 \rightarrow N_2$

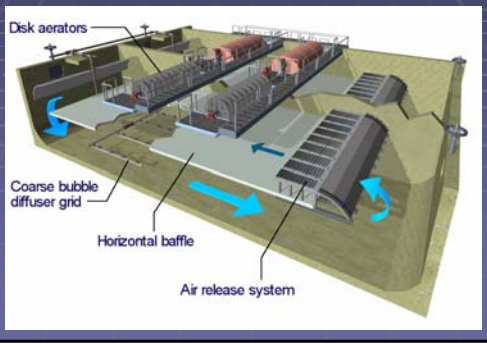
- Nitrobacter 量遠比 Nitrosomonas
量少可証明以上反應的存在

Typical Orbal™ Process Installation
典型的Orbal™工艺安装

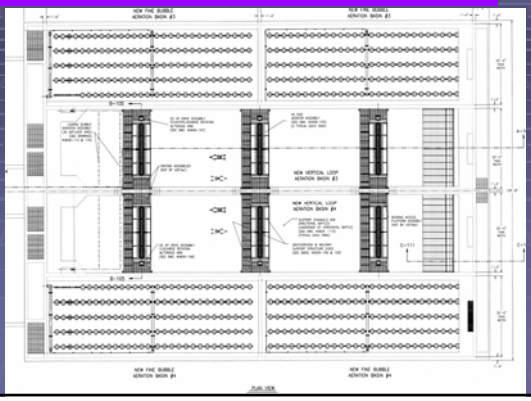
Combined Mechanical/Fine Bubble Process
机械/细气泡复合工艺



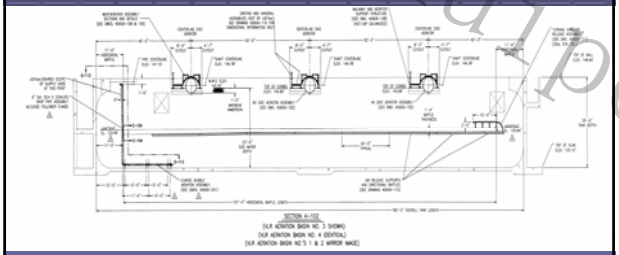
Vertical Loop Reactor (VLR)
立式环流反应器



TYPICAL VERTICE LAYOUT



TYPICAL VLR SECTION



VLR Rotating Disc Aeration
立式环流反应器转盘曝气

Brookfield, OH
Vertical Loop Reactor (VLR) Process

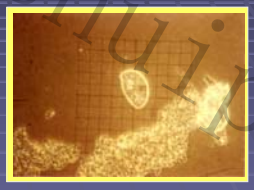
Peru, IN VLR / Cannibal Process

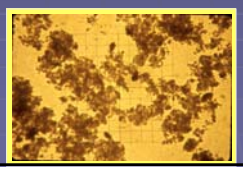
Hurricane, WV Two Train VLR System

Verticel活性污泥工艺

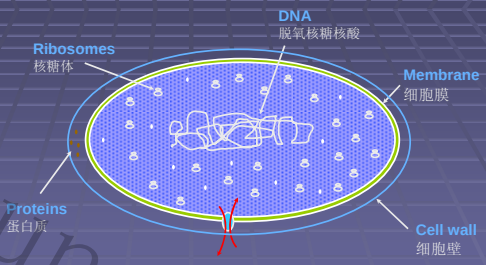
微生物学原理

Activated Sludge Microbial Ecology
活性淤泥微生物生态学



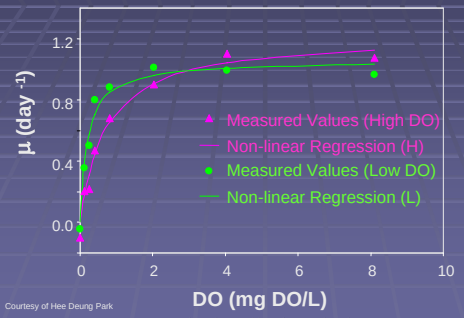


Cell Composition 细胞构成



Courtesy of Dan Nguyen

Kinetic Parameters



Courtesy of Hee Deung Park

提高充氧效率、节省曝气能耗的途 径

- ∝系数——污水中充氧速率与清水中充氧速率的比值
- 生物处理系统的泥龄
- 污水水质。

Clean Water Oxygen Transfer
清 水 氧 转 移

$$N\,(kg\,O_2\,/\,time) = K_L a(C_S - C)V$$

$K_L a$ = mass transfer coefficient 质量交换系数

C_S-C=driving force. 动力

C=0 mg/l at std conditions 标准状态下为 0mg/l

Aeration Design Considerations
曝气设计需要考虑的事项

$$SOTR = \frac{AOR}{FCF}$$

SOTR – Standard oxygen transfer rate, kg/day
标准氧气转移率, kg/day

AOR – Oxygen demand in process water, kg/day
工艺水的需氧量, kg/day

FCF – Field correction factor
现场修正系数

Aerator Field Correction Factor
曝气现场修正系数

$$FCF = \alpha\text{-}\frac{[(\beta)(ACF)(SCF)(C_{SW} - C)]}{(C_{SS})(SCF)}\text{-}1.024^{(T-20)}$$

Alpha * $\alpha = K_L a_{(field)} / K_L a_{(standard)}$

Beta $\beta = C_{S\,(field)} / C_{S\,(standard)}$

Theta

temperature

elevation

dissolved oxygen concentration*

diffuser submergence

* most important factors最重要因素

Alpha Depends On: 以下因素决定 Alpha

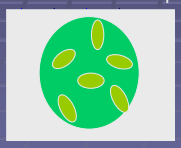
Type of aeration reactor

- 曝气反应器的类型
- Type of aerator
- 曝气机的类型
- Location in aeration system
- 曝气装置的位置
- Wastewater characteristics
- 污水的水质

VertiCel O_2 Transfer Efficiency

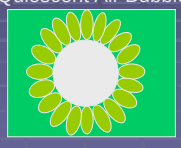
- Raw wastewater with surfactants has higher transfer efficiency with mechanical aerators.

Turbulent Water Droplet



Surfactants in suspension

Quiescent Air Bubble



Surfactants act as barrier

Alpha in Plug Flow System
活塞流系统中的 Alpha

Aerator Type	Location Inlet	Outlet
Fine Bubble	0.2 - 0.4	0.6 - 0.8
Coarse Bubble	0.7 - 0.8	0.7 - 0.8
Mechanical	1.0 - 1.2	0.9 - 1.0

Alpha in Complete Mix System
完全混合系统中的 Alpha

Aerator Type	Sludge Age 4 day	10 day	20 day
Fine Bubble	0.4	0.55	0.70
Mechanical	1.2	1.1	1.0

Field Correction Factors曝气现场校正系数

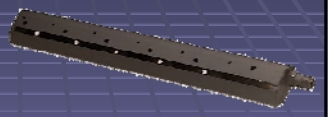
- Biggest factors are alpha and operating DO
  最大的因素为alpha和实际操作中的溶解氧气量
- Alpha - "low" for diffused air device (particularly fine bubble), "high" for mechanical surface aerators.
  Alpha -气扩散曝气设备的Alpha低(尤其是细气泡)，机械曝气设备的Alpha高
  - End result - an "efficient" mechanical aerator can approach (or exceed) fine bubble efficiency in the field - roughly 2.5-3 lb O_2/hp/hr
    最终结果 - 一台"有效"的机械曝气机可以接近（或超过）细气泡曝气功效 – 大概2.5-3 lb O_2/hp/hr
- Staging reactors with low initial DO can provide significant energy benefits (selectors)
  初始溶解氧气量的多级反应器可以提供显著的能量效益（选择器）
- Aerated anoxic zones further enhance staged DO approach
  曝气缺氧区继续增加进程溶解氧气量

Aeration Devices 曝气装置

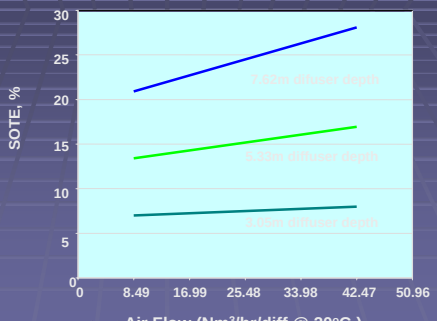
- Diffused Aeration 扩散式曝气
- Mechanical Aeration 机械曝气
- Combination Devices 复合装置

Aeration Devices - Diffused Air
曝气装置-空气扩散曝气

- Diffused Aeration
- 扩散式曝气
  - Coarse Bubble粗气泡曝气设备
    - Snap Caps, Wide Band, Air Band, Discfuser, oth



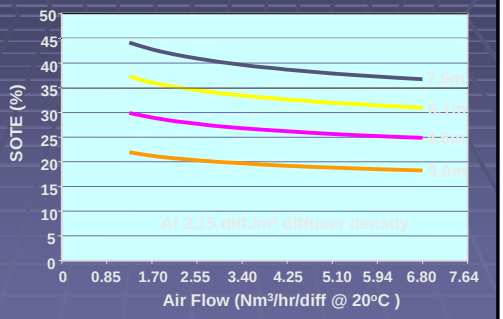

Coarse Bubble Diffuser SOTE
粗气泡曝气管标准氧气的转换效率



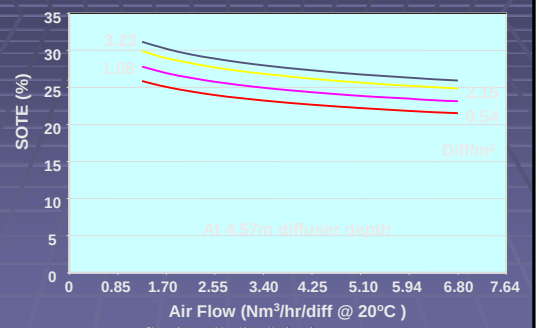
Aeration Devices – Diffused Aeration
曝气装置扩散式曝气

- Diffused Aeration
  扩散式曝气
  - Fine Bubble细气泡曝气设备
    - Ceramic and membrane discs 陶瓷和膜片
    - Ceramic and membrane tubes 陶瓷和膜管
    - Others 其它


Fine Bubble Diffuser SOTE Dependency on Depth
细气泡曝气管标准氧气的转换效率取决于深度



Fine Bubble Diffuser SOTE Dependency on Diffuser Density
细气泡曝气管标准氧气的转换效率也取决于密度



Disk Aerator 转盘曝气机

Aerator Clean Water Transfer
曝气机清水转移

Aerator Type	Comments	SAE kg/kw/hr
Coarse Bubble	Low maintenance. Low oxygen transfer efficiency.	1.2-1.8 kg/kw/hr
Fine Bubble	High clean water transfer efficiency. Potential for fouling, higher maintenance.	3.0-5.5 kg/kw/hr
Low Speed Aerators	Good aeration efficiency, mixing efficiency. Maintenance with gear reducer, aerosols.	1.5-2.1 kg/kw/hr
High Speed Aerators	Low initial cost, flexible operation. Lower aeration efficiency, shallow mixing, aerosols	1.1-1.3 kg/kw/hr

Source: WEF Manual of Practice 8

Aerator Clean Water Transfer
曝气机清水转移

Aerator Type	Comments	SAE lb/hr/hp
Horizontal (brush)	Accessible for maintenance. Good aeration efficiency. Limited tank geometry, aerosols.	1.5-2.1 kg/kw/hr
Horizontal (disc)	Accessible for maintenance. Good aeration and mixing efficiency with less aerosols. Limited tank geometry.	1.5-2.1 kg/kw/hr
Aspirating Aerators	Low cost, flexible. Low transfer efficiency, limited mixing.	0.5-0.8 kg/kw/hr
Jets	Good mixing, high SOTE. Lower SAE, requires pumps and blowers.	2.2-3.5 kg/kw/hr

Source: WEF Manual of Practice 8

应用不同曝气设备组合实现节能示例

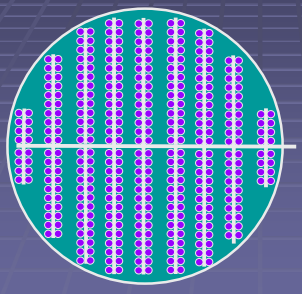
Comparison of Three Aeration Systems

- Flow: 2.16 mgd
- BOD_5: 500 mg/L
- NH_3 - N: 75 mg/L

Design Conditions:

SRT: 20 day
Carb. oxygen demand: 1.25 lb O_2/lb BOD_5
Nit. oxygen demand: 4.6 lb O_2/lb NH_3-N
Denit. credit: 2.3 lb O_2/lb NH_3-N @ 80% denit.

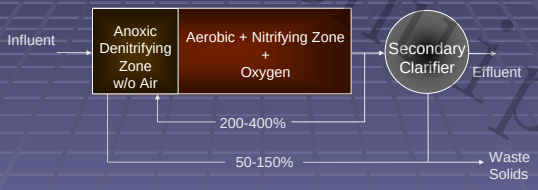
Complete Mix Fine Bubble System



AOR: 728 lb/hr
DO: 2.0 mg/L
Alpha: 0.55
FCF: 0.447
SOTR: 1,629 lb/hr

Power: 262 eHP

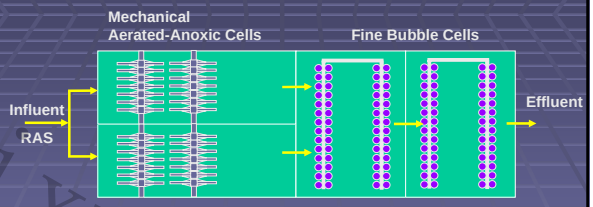
Conventional BNR



AOR*: 600 lb/hr
DO: 0/2.0 mg/L
Alpha: 0.60
FCF: 0.488
SOTR: 1,230 lb/hr

Power: 230 eHP

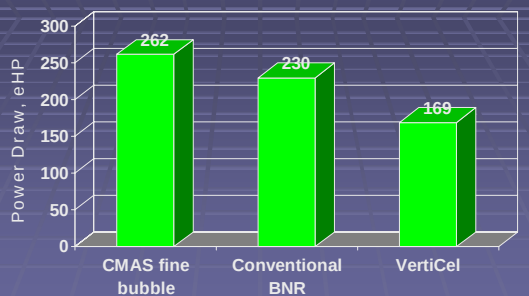
VertiCel Aeration System



AOR*: 600 lb/hr
DO: 0/1.0/2.0 mg/L
Alpha: 0.95/0.66/0.75
FCF: 1.04-0.93/0.63/0.61
SOTR: 806 lb/hr

Power: 169 eHP

Power draw comparison



Oxygen Delivery Efficiency

	lb AOR/hr/eHp
CMAS Fine Bubble	2.77
Conventional BNR	2.60
VertiCel	3.55