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Energy management and efficient electrification series for Ontario municipalities

Inflating your savings: optimizing blower systems in wastewater treatment plants

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Overview

1. Introduction
2. Blower technologies and sizing
3. Optimizing for efficiency – a total system approach
   - Upstream equipment
   - Downstream equipment
   - Measurement and metering
   - Controls
4. Municipal wastewater treatment plant (WWTP) training with LAS
   - Workshop and Treasure Hunt

Why are we reviewing blower system efficiencies?

Aeration typically accounts for between 40% and 70% of a water pollution control plant (WPCP) overall energy expenditures.

In Ontario, this equipment can significantly impact global adjustment costs for Class A clients.

Where are they used?

- ✓ Aeration tanks
- ✓ Grit chambers
- ✓ Channel blowers
- ✓ Aerobic digestors

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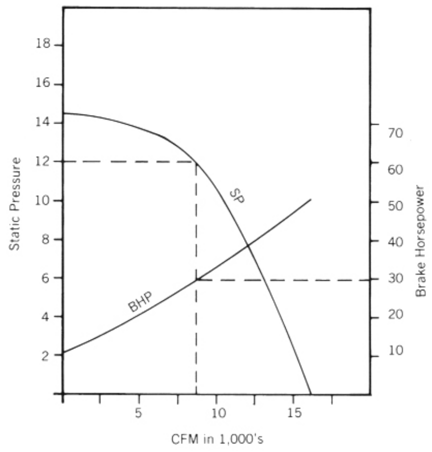
Blower system optimization

Total system approach

- Review with not only an operations lens, but also an energy optimization lens
- Look at upstream processes that affect blower power requirements
- Review downstream piping distribution and diffusers
- Clarify current air requirements due to system design
- Audit/improve measurement and monitoring
- Enhance controls



Blower technologies and sizing

Aeration technologies

Blower type	Throttling (least efficient)	Variable speed drive (VFD) (most efficient)
Mechanical aerators	N/A	Common
Lobe type positive displacement	Never	Only practical method
Screw type positive displacement	Never	Only practical method
Multistage centrifugal	Very common	Very common
Geared singles-stage centrifugal	Uncommon	Uncommon
Gearless single-stage centrifugal	Uncommon	Always provided
Turbo blower		Always

Replacing your blowers? General design factors

Centrifugal blowers

- Offer a wide range of pressure and flow capacities
- Multistage models allow for higher turndown ratios
- Must operate on performance map
    - Flow too low or pressure too high = surge
    - Flow too high or pressure too low = choke
    - Performance varies with air density

Turbo blowers

- Magnetic vs. airfoil bearings
- Higher efficiency than conventional rotary lobe technology
- Small footprint reduces cost to design new and retrofit blower rooms
- Integrated package including blower, motor and controllers makes installation easier

Turbo blower limitations

- Can have a more limited operational range relative to pressure and airflow
- Limited on/off cycling due to airfoil bearing limits and limited wear on electronic components

Blower sizing – air/oxygen requirements

Determine minimum air demand for mixing:

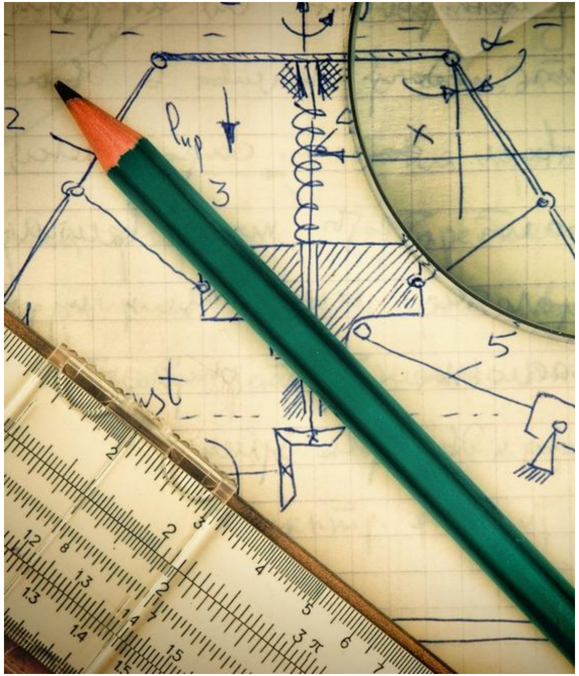
- For bioreactors, this is dependent on tank surface area
- For digestor aeration, it is based on tank volume

Determine minimum oxygen requirement for biological demand:

- Based on organic loadings to the bioreactors

Consider incorporating anoxic zones in bioreactors to reduce oxygen demand

For oversized systems, consider installing a **jockey blower** – "right size" system for average/current demand.



Field example - bioreactors

Background:

Influent loadings to bioreactors much lower than design – air demand for mixing > air demand for organic loading

Action:

Took one bioreactor offline

- Reduced overall aeration requirements
- Reduced energy consumption and load (kW), which reduced monthly bill and was helpful with global adjustment

Reducing blower loads by 50 kW will save:

- ~ $44,000 annually in electricity consumption costs
- Additional monthly savings from demand fees and possibly lower the following year's global adjustment fees.

Remember when optimizing airflow to ensure minimum design airflow is maintained. This is a function of dissolved oxygen (DO) requirements and the airflow required to keep mixed liquor solids from settling.

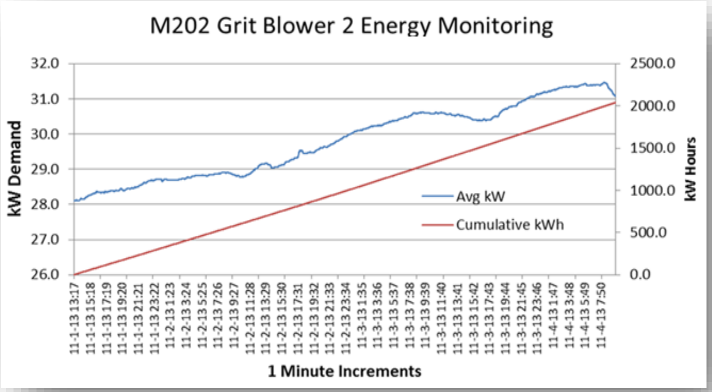
Field example - grit chamber aeration

Background:

Two blowers running in parallel with a combined load of ~ 60 kW into the aerated grit chambers

Airflow delivered seemed higher than expected given plant flow for the two grit chambers

Referred to original specifications and typical design values to determine optimal airflow (Medcaff and Eddy)



Action:

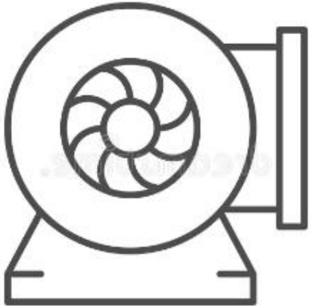
- Reduced blower operation from two to one
- Continuous load dropped by 50% (to 28-32 kW)
- Saved $37,000/year in electricity

Optimizing existing blower systems

System efficiency opportunities

Optimizing blower systems for efficiency

Blower technology



Upstream equipment

- ✓ Primary effluent quality
- ✓ RAS pumping

Downstream equipment

- ✓ Distribution piping
- ✓ Automatic and manual valves
- ✓ Small, medium and large bubble
- ✓ Diffusers

Measuring and metering

- ✓ Energy meters
- ✓ DO sensors
- ✓ Airflow meters
- ✓ Chemical oxygen demand (COD) analyzers
- ✓ Sentry analyzers

Controls

- ✓ Blower sequencing
- ✓ Mostly open valve (MOV) control
- ✓ Oxygen reduction potential (ORP)
- ✓ Pressure vs flow control

Upstream - process and equipment optimization

Primary clarifier performance

- Improving primary effluent quality reduces oxygen demand on downstream bioreactors

Approach: Careful control of sludge blankets, coagulant addition and polymer addition

Return activated sludge (RAS) pumping

- High RAS rates increase oxygen demand

Approach: Balance RAS pumping needs for clarifiers vs. bioreactors

Upstream process/equipment - influent

Municipal WPCP with large industrial contributors

➡ Additional organic loadings = additional oxygen demand

- Affects ongoing operational costs/energy use
- Affects required sizing of aeration system equipment (and possibly bioreactors)

➡ Additional organic loadings = more sludge

- Can affect aerobic digester/sludge holding tank aeration requirements

Possibility of pursuing cost recovery $$

Measurement and metering

- ✓ **Current sensors** (Amps) - can be used to estimate energy consumption
- ✓ **True power meters** – measures voltage and amperage (therefore power and energy consumption) and can indicate power quality issues
- ✓ **Airflow meters** – volumetric flow and mass flow
- ✓ **DO (Dissolved Oxygen) sensors**
- ✓ **COD (Chemical Oxygen Demand) analyzers** – influent or post-primary flow characterization
- ✓ **Sentry** – indicator or surrogate for readily biodegradable biochemical oxygen demand (BOD)

Measurement and metering – energy metering

Current sensors (Amps):

- Can be used to estimate energy consumption
- Cost-effective option to track motor amps that can be converted into power and energy consumption
- Less accurate than true power meters
- Available in wireless removable models

Power meters:

- Measure voltage and amperage (therefore power and energy consumption)
- Can help identify power quality issues
- More expensive but also more accurate
- Hardwired

Measurement and metering – airflow meters

- Two types of measurement: **Volumetric flow** or **mass flow**
- Both are used for feedback-based DO control
- Flow is often expressed as SCFM (standard cubic feet per minute), which appears to be volumetric flow but is defined for standard conditions so air will have a fixed density
- Should be calibrated at least once/year

Measurement and metering – dissolved oxygen

- Need to be calibrated frequently
- Complete periodic spot checks with a hand-held DO sensor to make sure they are not drifting

Location is important!

- ✓ Permanent DO sensors should be positioned 2/3 to 3/4 of the way along the aeration tank
- ✓ If permanent sensors are too close to the end, you will under-aerate; if placed too close to the head of the tank, you will over-aerate

Measurement and metering – additional devices

Real-time organic loadings

- Technologies that rely on surrogate measures for BOD
- Can be used for influent (raw) wastewater or primary effluent
- COD analyzers – directly measure COD; require a relationship between BOD and COD – site specific
- Sentry – biomass generating electrical current as surrogate for readily biodegradable BOD; requires a baseline for BOD – site specific

Measurement and metering – global adjustment

When is it OK to temporarily reduce/shut down aerators?

✓ **Stable plant operation**

- Consistent effluent quality
- Target mixed liquor suspended solid (MLSS) concentrations
- Well-settling mixed liquor

✓ **Duration**

- 4-8 hours – low impact
- Operational adjustments required – return activated sludge (RAS)/ waste activated sludge (WAS) pumping
- Length/temperature – odour potential on startup

✓ **Savings could be significant**

(50 kW motor x ~$60/peak/kW x 5 peaks = $15,000)

Your Electricity Charges

Cost of Power	0.02739 /kWh	531,899.80 kWh	14,567.94
Class A Global Adj 0.0000372			31,738.93
Class A - CBDR			146.22
Fixed Customer Charge	110.0148 /Day	31 Days	3,410.46
Distribution Charge	1.8867 /kW	1,121.56 kW	2,116.04
Transmission Network Charge	2.6736 /kW	1,121.55 kW	2,998.58
Transmission Connection Charge	2.6732 /kW	1,121.55 kW	2,998.13
Wholesale Market Service Charge	0.0035 /kWh	531,899.80 kWh	1,861.65
SSS Administration Charge	0.0082 /Day	31 Days	0.25
Transformer Allowance	-0.6000 /kW	1,121.55 kW	-672.93

Remember it would likely require 10-15 reduction events to ensure you hit the five Ontario peaks.

Typically, peaks occur on the hottest days of the summer in late afternoon.

Downstream equipment – air distribution headers

- Changes or expansions to distribution piping may not be designed to minimize friction or optimize performance
- Watch for unbalanced loading and constrictions
- Consider better manifold design to more effectively control airflow splits between tanks
- Tapered aeration in plug-flow bioreactors

Fix all leaks – even if they seem small as they can be costly

¼" orifice hole on a 70-psig system can lose ~75 CFM

Downstream equipment - valving

Manual and automatic valves

- Ensure that automatic valves are maintained and have been exercised through full range
- Avoid using manual valves to reduce flow to system as this increases downstream pressure (friction), which will increase the load on the motor
- Use motor control to reduce speed of blower to reduce airflow instead

Remember the Fan Laws:

1. CFM varies with RPM
2. Static Pressure (SP) varies with RPM^2
3. Break horsepower (BHP) varies with RPM^3

This means that significant power savings can be realized by a much smaller change in blower speed.

Field example - manual valves on air header

Background:

- Fully automated Turbo Blower
- Currently investigating why both manual valves are partially closed
- Using throttling valves downstream should be minimized as it increases power requirements

Downstream equipment - diffusers

Aeration tank diffusers

- Ceramic disc (can get fouled), membrane diffusers becoming more common
- Maintain once per year
- Check pattern of bubbles on surface to identify issues (clogged/broken air header/diffusers)

Channel or grit aeration

- Medium or large bubble diffusers – e.g. perforated piping
- Should be a wall of bubbles in grit tank – uneven if plugged

Diffusers in aerobic digestors

- Typically, medium bubble diffusers
- Design should not be susceptible to plugging during frequent shutdowns as per Ministry of the Environment, Conservation, and Parks (MECP) guidelines
- Check pattern of bubbles on surface

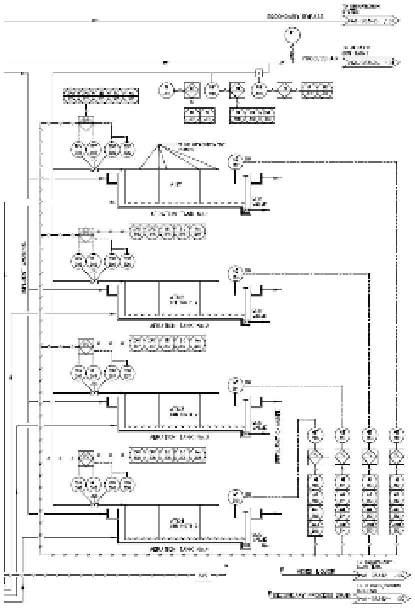
Aeration blower control

System objectives:

- Satisfy oxygen demand of treatment process
- Achieve process requirements at lowest possible cost

Several areas of opportunity:

- Mostly open valve (MOV) control
- Oxygen reduction potential (ORP) control
- Blower sequencing
- Anoxic zone
- Blower control to maintain investment



Aeration blower control – general terms

Blower control mechanisms (how):

- Variable frequency drives (VFDs)
- Inlet valve throttling – multistage centrifugal blowers
- Guide vane controls: inlet vanes = discharge pressure control, outlet vanes = blower capacity

Blower airflow control (how much):

- Constant/Variable system pressure
- Mostly Open Valve control (MOV control)
- Flow control

Aeration blower control – MOV control

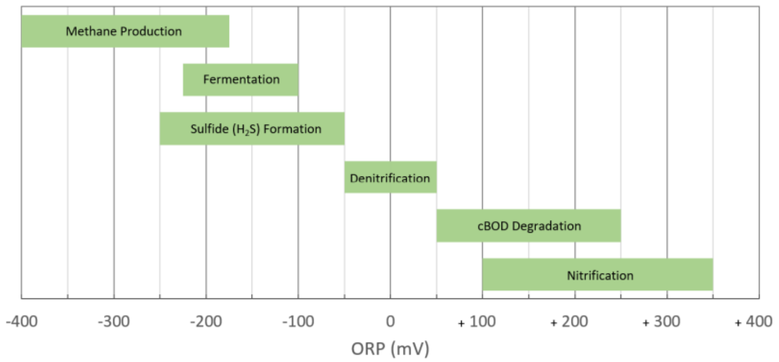
Mostly open valve (MOV) control: Up to 10% increase in efficiency

- With a common header, upstream pressure is equal at all tanks; the pressure drop across all valves is therefore the same
- Upstream pressure is determined by the valve at the position with the lowest pressure drop (or most open valve)
- With programming, the system can be controlled to adjust the system valve calling for the most air to run 100% open

Aeration blower control – ORP control

Oxygen reduction potential (ORP) control:

- Useful for plants wishing to further reduce DO targets (i.e. running at lower-than-conventional DO)
- Combined with DO measurements, can confirm the type of biological process(es) in progress in real time
- Also useful for on/off aeration (e.g. Sequential Batch Reactors (SBRs))



Aeration blower controls – Other Opportunities

Multiple blower sequencing

- Program controls to run blowers at the highest efficiency range on their curves
- Motors typically become much less efficient if the load is less than 50%
- Consider installing an additional smaller jockey blower to run when requirements are low or, as a top up, a larger blower. This is allowed within most ECAs (Environmental Compliance Approval) if the main blowers are not impacted.

Consider adding an anoxic zone

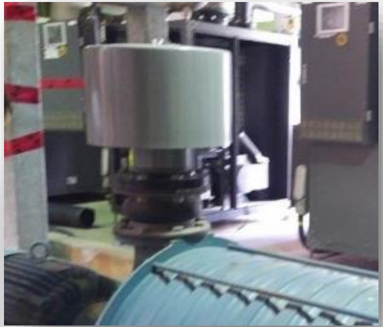
- Reduces oxygen requirement

Blower control to maintain investment

- Optimize control programming to manage the frequency of airflow changes to match process lag
- Increase wear and tear of turbo blowers if they are cycled off and on too frequently

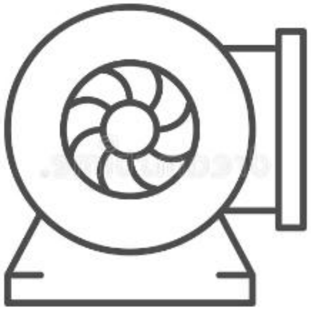
Maintenance considerations

- Inlet air ducts and filter cleaning
- Diffuser cleaning (remove fouling)
- Tank cleaning (remove debris)
- High temperature outlet air



Optimizing blower systems - summary

Blower technology



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Municipal case study: WWTP energy workshop and treasure hunt

Municipal WWTP – Northern Ontario

- Daily treatment - 20,000 m^3 per day
- Hydraulic capacity - 81,000 m^3 per day
- Secondary treatment – 52,000 m^3 per day
- Built in 1960s with recent upgrades in 2013
- Classified as conventional secondary treatment process

Treasure hunt - searching for savings

1. Pumps: pump upgrades, pumping sequence, pump controls
2. Aeration: control valves, DO sensors, pressure sensors, filtration maintenance, turbo blowers
3. HVAC: heating source, controls, set points

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The hidden treasure

- Rooftop Units duct/insulation repair
- Replace EM drive with VFD in older station – end of life
- Jockey blower replacement
- Maximize biogas usage – biogas to electricity vs heat
- LED upgrade – T12/CFL/metal halide

Lessons learned – the power of the collective

- The unique ability to identify energy savings when we come together as a team.
- "If you want to go fast go alone; if you want to go FAR go together"

Multiple resources available

Find multiple type of resources on Save on Energy website:

https://saveonenergy.ca/Training-and-Support

- **Webinars**
- **Fact sheets**
- **M&V templates**
- **Practical guides**

Sign up for one-on-one coaching: Post-webinar support intake form

- Coaching sessions conducted virtually by phone, video calls, and email
- Designed for organizations seeking guidance

Thanks for the opportunity to be of service!

"The help desk is now open!"

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