City of Taunton

Wastewater Treatment Facility
Energy & Greenhouse Gas Impact Assessment

October 2020

Conducted by:

JKMuir, LLC in coordination with **BETA Group, Inc.**

Table of Contents

Index of Tables

List of Appendices

Executive Summary

This report provides an energy evaluation and greenhouse gas (GHG) assessment of the preliminary design for the comprehensive upgrade of the Taunton, MA Wastewater Treatment Facility (WWTF) developed by Beta Group. The following summary provides detailed calculations and data as required in the *Certificate of the Secretary of Energy and Environmental Affairs on the Third Notice of Project Change* under the “Greenhouse Gas (GHG) Emissions” section. This memo quantifies the energy consumption and greenhouse gas impacts of the proposed design elements as issued by the Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs as part of the Comprehensive Wastewater Management Plan (CWMP) for Taunton.

The following sections outline the specific design elements that provide energy and GHG reductions along with corresponding calculations. The existing energy use data is based on previous testing and operational data collected at the facility by JKMuir and summarized in the *2017 City of Taunton Wastewater Treatment Facility Energy Evaluation.* The data collected at the facility in addition to historic plant operational and energy usage data was used to determine the “Base Case” energy usage for this evaluation The proposed design for the WWTF will be used to calculate the proposed energy use of the process systems at the facility and presented as the “Proposed Case”. Specific systems that have been evaluated for energy and GHG impact include the following:

- Grit Blowers,
- Primary Sludge Pumps,
- Aeration System
- Internal Recycle Pumps,
- Thickened Sludge Pumps,
- Reaeration Blowers,
- Plant Water System,
- Odor Control System,
- Premium Efficiency Motors,
- Variable Frequency Drives (VFDs), and
- Building Systems including Heating, Ventilation, and Air Conditioning (HVAC) and Lighting.

The objectives of the report include the following:

- Determine the energy impact of each proposed process upgrade listed above.
- Determine the associated GHG emissions impact for each proposed process upgrade listed above.
- Provide a description of the calculations and approach for the energy and GHG impact of each unit process upgrade.
- Summarize the “Base Case” and “Proposed Case” annual energy use, energy impact and associated GHG emissions in a summary table.

Summary of Energy Use and Environmental Impact of Upgrades

The following tables present the annual electric energy use of the plant; and a proposed estimate of potential energy conservation and GHG mitigation for the proposed preliminary design.

The energy usage summary shown below provides an overview of annual electrical use (kWh) and costs based on billing information provided for 2016 and 2017 for the facility.

Table 1. Electric Energy Usage (Sept 2016 – Aug 2017)

Location	Annual Energy Use (kWh)	Avg. Monthly Demand (kW)	Annual Cost ($)	Unit Cost ($/kWh)
Taunton WWTF	3,306,600	537.9	$368,231	$0.11

The following table presents a summary of the estimated annual energy and GHG impact of each unit process upgrade based on the existing equipment and design information provided by the design engineer.

Table 2. Summary of Environmental Impacts of Upgrades

Unit Process Upgrade	Base Case Energy Use (kWh)	Proposed Case Energy Use (kWh)	Annual Energy Impact (kWh)	Annual Cost Impact ($ per year)	GHG Impact ($MTCO_2e$)
Grit Blowers	100,025	61,925	38,099	$4,229	12.68
Primary Sludge Pumps	78,840	25,716	53,124	$5,897	17.68
Aeration System	9,288,836	2,849,471	6,439,364	$714,769	2,143.35
Internal Recycle Pumps	121,150	31,224	89,926	$9,982	29.93
Thickened Sludge Pumps	42,546	24,960	17,586	$1,952	5.85
Reaeration Blowers	484,599	461,971	22,628	$2,512	7.53
Plant Water System	783,360	391,680	391,680	$43,476	130.37
Odor Control System	160,995	103,955	57,039	$6,331	18.99
Total	**11,060,350**	**3,950,903**	**7,109,447**	**$789,149**	**2,366.39**

Energy & GHG Impact Assessment

The purpose of this evaluation is to quantify the energy and greenhouse gas (GHG) impact of the preliminary design for the comprehensive upgrade proposed for the WWTF. These opportunities include the installation of more efficient equipment and modifications to control strategies and processes. The following summary of the plant wide energy evaluation identifies design elements and unit processes proposed to be implemented to achieve cost and energy savings and corresponding GHG mitigation. The following sections provide detailed calculations and discussion of the design elements included in the preliminary design. Additional unit processes that were evaluated as part of this report that do not demonstrate reduction in energy use have not been presented in the following sections. The WWTFs highest priority is to public health and meeting the NPDES permit requirements, in some cases, the proposed upgrades require an increase in energy use as compared to current demand.

The GHG impact of these design elements was also quantified based on the requirements of the Massachusetts Environmental Policy Act Office (MEPA) GHG Policy issued on May 5, 2010. This policy requires the quantification of carbon dioxide (CO_2) and measures to avoid, minimize, or mitigate such emissions. The following analysis presents the GHG mitigation based on "indirect emissions" from electrical energy production. The proposed comprehensive upgrade includes limited modifications to systems that use fossil fuels or "direct emissions".

GHGs are quantified based on regional emission equivalent rates as quantified in the Environmental Protection Agency's (EPA's) Emission and Generation Resource Integrated Database (eGRID) from 2018 for Massachusetts under the State Output Emission Rates. The GHG emission quantification is based on CO_2 equivalents, which includes CO_2, methane, and nitrous oxide. GHG units are presented in metric tons carbon dioxide equivalents per year ($mtCO_2e/yr$).

Design Element Unit Process Energy & GHG Impact Calculations

The design elements for unit processes included in the proposed comprehensive upgrade that provide energy savings and GHG reduction are summarized in the following sections. A brief description of the existing and proposed processes are presented followed by quantification of the base and proposed energy use and the "indirect" GHG emissions associated with the proposed project. The conclusion presents the benefits of the proposed project in addition to the impact on the NPDES permit.

#1 Grit Blower Replacement

The facility headworks includes two aerated grit chambers where both chambers operate in parallel on a continuous basis. Under existing conditions air is supplied by two 7.5 hp positive displacement blowers that operate continuously at constant speed. Often times, grit removal systems are over-aerated. Adequate operation of these systems may be maintained with reduced air flow, allowing for improved electrical efficiency. During the design phase of the comprehensive plant upgrade it was determined that two smaller blowers could provide sufficient airflow to the aerated grit chambers. The design specifies two new 5 hp positive displacement blowers to replace the existing 7.5 hp blowers. A reduction in the blower size will result in energy and GHG savings.

Base Case

Under the baseline conditions, the existing two grit blowers operate continuously with an equipment loading of 85%. The base case electrical consumption is presented in the following table.

Table 3. Grit Blowers – Base Case Energy Usage

Quantity of Blowers	Horsepower per Blower	Motor Efficiency (%)	Power Draw per Blower (kW)	Annual Hours of Operation	Annual Energy Use (kWh/yr)	Annual GHG Emissions ($mtCO_2e$/yr)
2	7.5	83.3%	5.7	8,760	100,025	32.29

Notes:

1. Blower quantity and horsepower based on existing grit blowers.
2. Motor efficiency from page 62/136 of the DOE's "Premium Efficiency Motor Selection and Application Guide" for premium efficiency motor.
3. Power draw calculated using motor horsepower, motor efficiency, and an 85% loading factor.
4. GHG emissions based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Proposed Case

For the proposed case, the energy usage of, two 5 hp Howden positive displacement blowers was estimated. The size of proposed grit blowers for the comprehensive upgrade were determined based on a typical grit chamber air requirement of 5 cfm/lf (cubic foot per minute per linear foot). The proposed case energy usage is presented in the following table.

Table 4. Grit Blowers – Proposed Case Energy Usage

Quantity of Blowers	Horsepower per Blower	Motor Efficiency (%)	Power Draw per Blower (kW)	Annual Hours of Operation	Annual Energy Use (kWh/yr)	Annual GHG Emissions ($mtCO_2e/yr$)
2	5.0	89.7%	3.5	8,760	61,925	20.61

Notes:
1. Blower quantity and horsepower based on proposed grit blowers.
2. Motor efficiency from page 62/136 of the DOEs "Premium Efficiency Motor Selection and Application Guide" for premium efficiency motor.
3. Power draw calculated using motor horsepower, motor efficiency, and an 85% loading factor.
4. GHG emissions based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Summary of Savings

A summary of the annual savings associated with this measure are presented in the table below.

Table 5. Grit Blowers – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e/yr$)
Base	100,025	$11,103	33.29
Proposed	61,925	$6,874	20.61
Savings	**38,099**	**$4,229**	**12.68**

Notes:
1. Cost savings based on unit cost of $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Conclusion

Reducing the motor size of these blowers will produce energy and GHG savings in addition to providing the benefit of adequate aeration for grit removal. The existing standard efficiency motors will be replaced with premium efficiency to reduce overall energy use. While the grit removal system does not directly impact maintaining the NPDES permit requirements, it removes grit to allow downstream treatment and equipment to operate more efficiency. The blower replacement provides a cost-effective method of reducing energy use while also replacing aged and less efficient equipment.

#2 Primary Sludge Pumps Replacement and Operational Modification

The design for the comprehensive upgrade includes replacing the three existing primary sludge pumps that are operated on VFDs continuously at reduced speed with four new, 25 HP primary sludge pumps that operate for a reduced amount of time per day. Under the existing plant operation there are three primary clarifiers, which the primary sludge pumps draw from. In the comprehensive upgrade design, a fourth primary clarifier is proposed to be installed along with four new primary sludge pumps. The design includes an operational modification which will maintain a specific sludge blanket in the primary tanks, and dedicate one pump per clarifier, which will reduce the total operating hours of the primary sludge pumps. The proposed design of the four 25 HP primary sludge pumps and primary clarifier operation will result in reduced energy usage of the primary sludge pumping system. The energy usage of the existing and proposed systems and the resulting savings are outlined in the following sections.

Base Case

Under the base case, the primary sludge pumps operate continuously on belt drives and VFDs. Typically, Pump 1 and 2 operate at a speed of approximately 52% and Pump 3 runs at approximately 68%. Based on the field measured power draw it was determined that the motors are lightly loaded at typical operating points. Operating motors under lightly loaded conditions decreases the motor efficiency and can cause operational and maintenance issues. JKMuir recorded field electrical readings, discharge pressures, wetwell levels and flows. The table below outlines the estimated annual energy usage of the primary sludge pumps based on the field-tested readings and information provided by facility staff.

Table 6. Primary Sludge Pumps – Base Case Energy Usage

Pump	Power Draw (kW)	Motor Load (%)	Estimated Motor Efficiency (%)	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions (mtCO$_2$e/yr)
PSP 1	3.1	16%	70%	8,760	27,156	9.04
PSP 2	2.9	14%	70%	8,760	25,404	8.46
PSP 3	3.0	15%	70%	8,760	26,280	8.75
				Total	**78,840**	**26.24**

Notes:
1. Power draw based on field measured readings.
2. Motor load based on power draw readings and motor nameplate horsepower.
3. Motor efficiency based on lightly loaded motor conditions.
4. Annual hours of operation based on information provided by facility staff.

Proposed Case

Under the proposed case, there will be four 25 HP primary sludge pumps with one dedicated to each clarifier. The primary sludge pumps will be operated on VFDs at full speed to maintain the sludge blanket. Based on discussions with the design engineer, the proposed pumps are anticipated to operate several minutes per hour (2.6 min/hour). The following table outlines the estimated annual energy usage based on the proposed design of the primary sludge pumping system.

Table 7. Primary Sludge Pumps – Proposed Case Energy Usage

Number of Pumps	Motor Horsepower	Motor Efficiency (%)	Power Draw per Pump (kW)	Annual Hours of Operation per Pump	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions ($mtCO_2e/yr$)
4	25	93.6%	16.9	380	25,716	8.56

Notes:

1. Number of pumps and motor horsepower based on information provided by design engineer.
2. Motor efficiency from page 62/136 of the DOEs "Premium Efficiency Motor Selection and Application Guide" for premium efficiency motor.
3. Power draw is based on motor horsepower, motor efficiency and assumed 85% equipment loading.
4. Annual hours of operation based on information provided by design engineer.

Summary of Savings

The estimated electrical and cost savings are presented in the table below.

Table 8. Primary Sludge Pumps – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e/yr$)
Base	78,840	$8,751	26.24
Proposed	25,716	$2,855	8.56
Savings	**53,124**	**$5,897**	**17.68**

Note:

1. Cost based on unit cost of $0.111/kWh.
2. GHG savings based on based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for MA.

Conclusion

Replacing the existing oversized pumps and operating them at a higher loading rate for reduced hours to maintain the sludge blanket will result in energy and greenhouse gas savings. The VFDs will also provide operational flexibility to modify the primary sludge flow based on flow and loading conditions to maintain proper treatment. By installing a fourth clarifier and modifying operation of the primary sludge pumps, the plant will be able to remove suspended solids and BOD more effectively at the primary stage to meet the NPDES permit requirements. These modifications reduce energy consumption and may more effectively remove suspended solids and BOD to meet permit requirements.

#3 Aeration System Upgrade to Fine Bubble

The Taunton WWTF currently uses a combination of surface aerators and fine bubble diffusers for aeration of the secondary treatment process. Aeration is provided with two batteries of tanks. Battery 1 receives 35% of the plant flow, and Battery 2 receives 65% of the plant flow. Each battery contains three basins, two of which are aerated with surface aerators and one of which is aerated using fine bubble diffusion. Half of the flow is sent to the fine bubble diffusion basin and half is split evenly between the two surface aerator basins for each battery.

Aerator energy consumption is dependent on the oxygen demand in the aeration tanks. The oxygen required to sustain the biomass and maintain adequate treatment varies based on the concentration of organic material entering the tanks, the flow rate through the facility, and the wastewater temperature. Both the flow and the organic loading to the facility fluctuate seasonally, resulting in different aeration requirements during each month of the year. The volume of air that is required to provide the necessary oxygen to support the biological treatment process is dependent on the air temperature, humidity, water depth in the tanks, and the efficiency of the mechanical surface aerators.

The proposed comprehensive upgrade design requires increased airflow to the biological treatment system to meet the new nutrient removal requirements for the NPDES permit. Due to the increased airflow requirements the energy usage of the aeration system will increase compared to existing energy usage. However, the proposed upgrade specifies a fine bubble diffusion system with multistage centrifugal blowers with inlet throttling valve to meet the airflow requirements. Fine bubble aeration systems typically require less energy to operate compared to mechanical surface aerators. The following calculation outlines the energy savings resulting from operating a fine bubble aeration system compared to a mechanical surface aerator system to meet the proposed biological systems future airflow requirements.

Base Case

Under the base case, the required aeration for the biological treatment system to meet the new NPDES nutrient removal requirements would be provided entirely by surface aerators to mimic current operation. Overall, the base case is expected to have increased energy usage compared to the existing system as a result of the increased airflow requirements. Based on the airflow requirements of the proposed fine bubble system provided by the design engineer, the actual oxygen requirement for both the average and maximum expected operating conditions was modeled, as shown in the table on the following page.

Table 9. Aeration – Actual Oxygen Requirement (AOR)

Condition	Airflow Required (cfm)	lbs O_2 per cubic foot	SOR (lb/min)	AOR/SOR Fine Bubble	AOR (lb/min)	AOR (lb/hr)
Average	10,000	0.0173	173	0.33	57.09	3,425
Maximum	14,700	0.0173	254	0.33	83.92	5,035

Notes:

1. Average and maximum airflow conditions based on proposed aeration system conditions provided by design engineer.
2. Pounds oxygen per cubic foot (lbs O2 / CF) is based on standard conversion.
3. AOR/SOR for fine bubble systems based on industry standards.

The anticipated AOR under the average and maximum conditions is then used to determine the standard oxygen requirements (SOR) for the surface aerator system, based on the following equation:

$$AOR = SOR(\alpha)\left[\frac{\left[\beta\left(\frac{Pf}{PMSL}\right)C_{sat_T}\right] - DO\ field}{C_{sat_{20}}}\,\theta^{T-20}\right]$$

The terms for this equation and assumptions for the calculated oxygen requirements are further defined below:

1. AOR was determined using the average and maximum airflow requirements of the proposed fine bubble system. The average and maximum airflows were provided by the design engineer.
2. Pressure values:
    a. Pf is the barometric pressure at the project location.
    b. PMSL is the barometric pressure at mean sea level.
3. Typical values for the following parameters that correct for the differences in the dissolved solids and oxygen transfer characteristics of wastewater versus clean water:
    a. α (alpha) = 0.82 (ratio of mass transfer coefficient of wastewater to clean water for mechanical surface aerators).
    b. β (beta) = 0.95 (saturation factor).
4. Typical industry standard value for Θ (theta), which corrects for the temperature of the wastewater through an exponent of T-20 (Θ^{T-20}).

5. The saturation DO concentration at standard conditions and typical average and maximum wastewater temperatures (C_{s20} and DO_{Sat}).
6. Based on the proposed aeration control, the average DO residual concentration for complete nitrification was set to 0.2 milligrams per liter (mg/L).

It was assumed the surface aerators would have a standard design oxygen transfer rate of 3.5 lbs of oxygen per hp-hour, which was used to determine the aerator under each condition. The aerators were assumed to operate continuously to provide oxygen to the biological reactors. It was estimated that the average airflow requirement will occur 95% of the time, and the maximum condition will occur 5% of the time. The energy consumption of the surface aeration system is presented in the following table.

Table 10. Surface Aeration System – Base Case Energy Usage

Condition	SOR lb./hr.	Design Transfer Rate (O2/HP-h)	BHP Surface Aerators	Motor Efficiency (%)	VFD Efficiency (%)	Power Draw (kW)	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions (mtCO2e/yr)
Average	4,470	3.5	1,277	95.0%	97%	1,036	8,322	8,621,782	2,869.77
Maximum	6,571	3.5	1,877	95.0%	97%	1,523	438	667,054	222.03
							Total	**9,288,836**	**2,647.74**

Notes:
1. SOR based on AOR calculated previously and AOR/SOR for surface aerators based on industry standard.
2. Oxygen transfer rate based on standard surface aerator transfer rate.
3. Aerators BHP based on site standards, AOR/SOR ratio for surface aerators and aeration calculation.
4. Motor efficiency based on premium efficiency standards for motors over 100 hp.
5. VFD efficiency based on typical thermal losses.
6. Annual operating hours for each condition assumed based on typical wet weather conditions at the WWTF.

Proposed Case

The proposed case is based on the aeration system design for the comprehensive upgrade. Under the proposed case, all basins have fine bubble diffusion with air provided by new 250 hp multi-stage centrifugal aeration blowers operated at constant speed with an inlet throttling valves. The blower inlet throttling valves can be modulated to meet varying air requirements of the aeration system. The design engineer anticipates that the average operating condition consists of two blowers providing 5,000 standard cubic feet per minute (scfm) at a pressure of 8.5 pounds per square inch (psi). The expected maximum condition is 4,900 scfm per blower at a pressure of 8.7 psi, with three blowers in operation. It was estimated that the average condition will occur 95% of the time, and the maximum condition will occur 5% of the time based on typical wet weather conditions at WWTFs. The table on the following page shows the proposed energy usage for the aeration blowers and fine bubble diffusion aeration system.

Table 11. Centrifugal Aeration System – Proposed Case Energy Usage

Condition	Number of Blowers	Flowrate per Blower (cfm)	Pressure (PSI)	Motor Efficiency (%)	Power Draw (kW)	Percent of Time	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions ($mtCO_2e/yr$)
Average	2	5,000	8.5	95%	317.3	95%	8,322	2,640,973	879.05
Maximum	3	4,900	8.7	95%	476.0	5%	438	208,498	69.40
							Total	**2,849,471**	**809.65**

Notes:
1. AOR based on the equation presented above.
2. AOR/SOR surface aerators based on industry standard calculation presented in the appendix.
3. Oxygen transfer rate based on standard surface aerator transfer rate.
4. Aerators brake horsepower (BHP) based on site standards, AOR/SOR ratio for surface aerators and aeration calculation.
5. Motor efficiency based on premium efficiency standards for motors over 100 hp.
6. Annual operating hours for each condition assumed based on typical wet weather conditions at the WWTF.
7. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Summary of Savings

A summary of the annual savings associated with this measure are presented in the table below.

Table 12. Aeration – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e/yr$)
Base	9,288,836	$1,031,061	2,647.74
Proposed	2,849,471	$316,291	809.65
Savings	**6,439,364**	**$714,769**	**1,838.09**

Notes:
1. Unit cost is $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Conclusion

Replacing the existing surface aerators with a more efficient alternative of fine bubble aeration provided by multistage centrifugal blowers provides energy savings and reduced GHG emissions. To meet the discharge permit requirements an increased volume of air is needed as compared to current operation. If the plant were to remain with surface aerators to provide this aeration, there would be a significant increase in energy use. The aeration system upgrades are directly related to maintain the NPDES permit specifically for BOD and nutrient removal. Without these upgrades, the plant may be unable to meet these more stringent requirements or use a significantly higher amount to of energy throughout the process.

#4 Internal Recycle (IR) Pump VFDs

Modifications to the existing aeration system for more effective nutrient removal includes the addition of internal recycle (IR) pumps. The proposed comprehensive upgrade design includes the installation of two 10 hp axial flow pumps, which will recycle flow from the effluent of the aeration tanks to the beginning of the anoxic tanks. The IR pumps aid in the enhanced treatment system to meet future NDPES permit nutrient removal requirements. The proposed pumps will be operated on VFDs to vary with plant influent flow. Typically, IR pumps may be sized for 400% of plant flow to meet peak plant flow and loading conditions. However, under typical flow and loading conditions at the Taunton WWTF, IR pumps are only required to operate at approximately 200% of plant flow. Installing VFDs and operating the pumps at reduced flow and speed result in reduced energy usage and GHG emissions.

Base Case

Under the base case, two pumps operate continuously throughout the year at a constant speed, returning IR flow to the head of the aeration trains. The base case includes pumps operating at full speed for 400% of the influent flow. The power draw was estimated using a typical loading factor of 85%. The following table presents the energy usage of the base case.

Table 13. IR Pumps – Base Case Energy Usage

Condition	Quantity of Pumps	Motor Horsepower (HP)	Motor Efficiency (%)	Power Draw per Pump (kW)	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions ($mtCO_2e/yr$)
Constant Speed	2	10	91.7%	6.9	8,760	121,150	40.32

Notes:
1. Quantity of pumps and motor horsepower based on information provided by design engineer.
2. Motor efficiency from page 62/136 of the DOEs "Premium Efficiency Motor Selection and Application Guide" for premium efficiency motor.
3. Power draw based on motor horsepower, motor efficiency and a loading factor of 85%.
4. GHG savings based on the MA emissions rate of 733.8 lbs CO2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Proposed Case

Under the proposed case, two pumps operate continuously throughout the year at a reduced speed of approximately 50% to meet 200% of the influent flow. Under average plant influent flow conditions, the IR pumps will operate at a reduced speed. The reduced speed is intended to reflect how the VFDs will vary based on the influent flow rate. The calculations for the proposed case energy use are outlined in the following table.

Table 14. IR Pumps – Proposed Case Energy Usage

Condition	Quantity of Pumps	Motor Horsepower (HP)	Motor Efficiency (%)	VFD Efficiency (%)	Power Draw per Pump (kW)	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions ($mtCO_2e/yr$)
50% Speed	2	10	91.7%	97%	1.8	8,760	31,224	10.39

Notes:
1. Quantity of pumps and motor horsepower based on information provided by design engineer.
2. Motor efficiency based on premium motor efficiency standard.
3. VFD efficiency based on typical heat losses.
4. Power draw based on motor horsepower and affinity laws.
5. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Summary of Savings

A summary of the annual savings and reduction in GHG emissions associated with this measure are presented in the table below.

Table 15. IR Pumps – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e/yr$)
Base	121,150	$13,448	40.32
Proposed	31,224	$3,466	10.39
Savings	**89,926**	**$9,982**	**29.93**

Notes:
1. Cost savings based on unit cost of $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Conclusion

Operating the IR pumps on VFDs at reduced speeds based on the influent flow allows the pumps to use less energy and reduce GHG emissions. Since the pumps are sized to meet the full design capacity of the plant, they do not need to operate at full speed the majority of the year. The flexibility of the VFD also allows the pumps to be adjusted based on changing flow and loading conditions, which vary diurnally and seasonally, without the overuse of energy. The IR pumps assist the aeration system in optimizing nutrient removal through the recycling of bacteria to the head of the aeration system. The IR pumps are a critical aspect of secondary treatment system for meeting the nutrient requirements of the NPDES permit.

#5 Thickened Sludge Pump VFDs

There are two existing 20 hp thickened sludge pumps at the Taunton WWTF that operate at constant speed when the sludge dewatering process is in operation. The thickened sludge is pumped from the gravity thickener to the two centrifuges. In the proposed comprehensive upgrade design, the two existing pumps are slated to be replaced with two new 20 hp peristaltic thickened sludge pumps and motors operated on VFDs. The proposed upgrade to replace the existing pumps and motors with new equipment operated on VFDs will result in energy and GHG savings.

Base Case

Under the base case, the thickened sludge pumps operate at constant speed. Based on information provided by the design engineer it was estimated that the sludge dewatering system operates approximately 8 to 16 hours per day (average of 12 hours), 5 days per week, 52 weeks per year. It was assumed that one thickened sludge pump operates when the sludge dewatering system is in operation. The power draw was determined using a loading factor of 85%. The following table outlines the estimated annual energy usage of the existing thickened sludge pumps.

Table 16. Thickened Sludge Pumps – Base Case Energy Usage

Condition	Quantity of Pumps	Motor Horsepower (HP)	Motor Efficiency (%)	Power Draw per Pump (kW)	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions ($mtCO_2e/yr$)
Constant Speed	2	20	93.0%	12.68	3,120	42,546	14.16

Notes:
1. Motor horsepower based on existing motor nameplate.
2. Motor efficiency based on premium motor efficiency standard.
3. Power draw is based on a loading factor of 85%.
4. Annual hours of operation based on typical sludge dewatering system operation.

Proposed Case

Under the proposed case, two new 20 HP peristaltic pumps and motors are operated on VFDs. The design engineer estimated the typical average pump rate is approximately 100 gpm. The system pressure was assumed to be 73 pounds per square inch (psi) based on the pump curve and a typical discharge pressure for a thickened sludge pump system. The manufacturers pump and power curve were used to estimate the power draw at the typical flowrate and assumed discharge pressure. The manufacturers pump curve for the proposed pump is attached in the appendix. The annual hours of operation were assumed to be the same as the base case. The table on the following page outlines the estimated annual energy usage for the proposed case.

Table 17. Thickened Sludge Pumps – Proposed Case Energy Usage

Condition	Quantity of Pumps	Flowrate per Pump (gpm)	Discharge Pressure (psi)	Power Draw per Pump (kW)	Annual Hours of Operation	Annual Energy Usage (kWh)	Annual GHG Emissions ($mtCO_2e/yr$)
Variable Speed	2	100	73	8.0	3,120	24,960	8.31

Notes:
1. Typical flowrate is based on information from the design engineer.
2. Discharge pressure is assumed to be 73 psi.
3. Power draw based on proposed manufacturer pump curve provided by design engineer.
4. Annual hours of operation based on typical sludge dewatering system operation.

Summary of Savings

The estimated electrical, cost and GHG savings are presented in the following table.

Table 18. Thickened Sludge Pumps – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e/yr$)
Base	42,546	$4,723	14.16
Proposed	24,960	$2,771	8.31
Savings	**17,586**	**$1,952**	**5.85**

Note:
1. Cost based on unit cost of $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for MA.

Conclusion

The replacement of the thickened sludge pumps and VFD operation will result in reduction in energy use and greenhouse gas while also maintaining the solids treatment process. The thickened sludge pumps transfer sludge from gravity thickening to the centrifuges for further thickening, operating at a reduced speed allows the pumps to reduce energy use while allowing for control over the flow and feed rate to the centrifuges. While the solids treatment train does not directly impact the NPDES permit, sludge processing is critical to the operation of the plant and effective removal of solid materials from the flow. Thickening the sludge on-site reduces trucking costs and greenhouse gas impacts of trucking by reducing the water weight.

#6 Reaeration Mechanical Surface Aerator VFDs

The Taunton WWTF will be installing a new reaeration system as part of the comprehensive upgrade. The proposed system includes two reaeration trains each with two surface aerators (four total). The four reaeration surface aerators will be operated continuously on VFDs at a reduced speed. Operating the surface aerators at reduced speeds will result in reduced energy usage and GHG emissions compared to constant speed operation.

Base Case

Under the base case condition, four 20 HP surface aerators are operated continuously at constant speed. The base case assumes the constant speed surface aerators have an equipment loading factor of approximately 85%. The following table outlines the base case energy consumption.

Table 19. Reaeration System – Base Case Energy Usage

Quantity of Surface Aerators	Horsepower per Surface Aerator	Motor Efficiency (%)	Power Draw per Surface Aerator (kW)	Annual Hours of Operation	Annual Energy Use (kWh/yr)	Annual GHG Emissions (mtCO_2e/yr)
4	20	91.7%	13.8	8,760	484,599	161.30

Notes:
1. Quantity and horsepower of surface aerators based on information provided by design engineer.
2. Motor efficiency for premium efficiency motors from page 62/136 of the DOEs "Premium Efficiency Motor Selection and Application Guide".
3. Power draw based on motor horsepower, motor efficiency and an 85% equipment loading factor.
4. Annual hours of operation based on expected continuous operation of reaeration system.
5. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Proposed Case

Under the proposed conditions, four 20 HP surface aerators will be operated on VFDs at a reduced speed. It was assumed that the aerators are operated at a reduced speed approximately 80% of the time and at full speed approximately 20% of the time based on varying flow and load conditions throughout the year. The equipment loading factor for the reduced speed operation was assumed to be approximately 77%. This is based on field tested power draw readings of surface aerators operating at low speed at similar facilities. The proposed case energy usage is outlined in the following table.

Table 20. Reaeration System – Proposed Case Energy Usage

Condition	Quantity of Surface Aerators	Horsepower per Surface Aerator	Motor Efficiency (%)	VFD Efficiency (%)	Power Draw per Surface Aerator (kW)	Annual Hours of Operation	Annual Energy Usage (kWh/yr)	Annual GHG Emissions ($mtCO_2e/yr$)
Full Speed	4	20	91.7%	97%	14.3	1,752	99,917	33.26
Reduced Speed	4	20	91.7%	97%	12.9	7,008	362,053	120.51
						Total	**461,971**	**153.77**

Notes:

1. Quantity and horsepower of surface aerators based on information provided by design engineer.
2. Motor efficiency for premium efficiency motors from page 62/136 of the DOEs "premium efficiency motor selection and application guide".
3. VFD efficiency based on typical thermal loses.
4. Full speed power draw assumes an equipment loading factor of 85%.
5. Reduced speed power draw assumes an equipment loading factor of 77%.
6. Annual hours of operation based on expected operation.
7. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Summary of Savings

A summary of the annual savings associated with this measure are presented in the table below.

Table 21. Reaeration System – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e/yr$)
Base	484,599	$53,790	161.30
Proposed	461,971	$51,279	153.77
Savings	**22,628**	**$2,512**	**7.53**

Notes:

1. Unit cost is $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Conclusion

The design of the reaeration system includes operating the aerators on VFDs at a reduced speed for a majority of the year to reduce energy and provide greenhouse gas savings. The effluent stream dissolved oxygen concentration is included in the NPDES permit requirements. Providing reaeration following the aeration system upgrades is required to meet these limits, where the previous treatment method may not have required additional aeration to meet these concentrations. Having the aerators on VFDs allows the plant operations staff to alter the speed and amount of aeration provided based on the dissolved oxygen present in the wastewater stream to minimize energy use and stay within the permit limits.

#7 Plant Water System Pressure Setpoint Reduction

The Taunton WWTF has an existing plant water system consisting of one 40 hp pump and one 20 hp pump, both operated on VFDs. Typically, the 40 hp pump operates at 100% speed continuously to maintain a system pressure setpoint of 160 psi. The existing system provides water to a number of processes throughout the plant including polymer batching, lime slurry in the chemical building, secondary clarifiers, chemical carry water, primary distribution box, wash down water, gravity thickener, and aeration effluent box.

The proposed comprehensive upgrade design includes the installation of six new constant speed 25 hp plant water pumps to replace the existing pumps. The proposed plant water pump curves are presented in the appendix. In the proposed upgrade, the flowrate of the plant water system is expected to increase significantly to provide additional plant water to the gravity thickeners. The proposed plant water system is designed to maintain a system pressure setpoint of 80 psi.

Significantly increasing the flowrate of the plant water system will result in an overall increase of plant water energy usage. However, the decrease in system pressure setpoint will result in less energy usage compared to a proposed system with the existing setpoint of 160 psi.

Base Case

Under the base case, it was assumed that two of the proposed plant water pumps operate continuously to maintain the existing system pressure setpoint of 160 psi. The following table presents the base case energy usage.

Table 22. Plant Water System – Base Case Energy Usage

Condition	Quantity of Pumps Operating	Flow per Pump (gpm)	TDH (ft)	Motor Efficiency (%)	Pump Efficiency (%)	Power Draw (kW)	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions ($mtCO_2e$/yr.)
Constant Speed	2	400	370	91.7%	68%	89.4	8,760	783,360	260.7

Notes:

1. Quantity of pumps and annual hours of operation assumed based on average expected conditions.
2. Flow, motor efficiency and pump efficiency based on preliminary plant water manufacturer data sheet provided by design engineer.
3. TDH based on existing plant water pressure setpoint from JKMuir previous energy audit.
4. Power draw determined using pump efficiency equation.
5. GHG savings based on the MA emissions rate of 733.8 lbs CO2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Proposed Case

Under the proposed case, it was assumed that two of the proposed 25 hp pumps operate at constant speed continuously to maintain a system pressure setpoint of 80 psi. The proposed case energy use is outlined in the following table.

Table 23. Plant Water System – Proposed Case Energy Usage

Condition	Quantity of Pumps Operating	Flow per Pump (gpm)	TDH (ft)	Pump Efficiency (%)	Motor Efficiency (%)	Power Draw (kW)	Annual Hours of Operation	Annual Energy Usage (kWh/yr.)	Annual GHG Emissions ($mtCO_2e$/yr.)
Constant Speed	2	400	185	68%	91.7%	44.7	8,760	391,680	130.4

Notes:

1. Quantity of pumps and annual hours of operation assumed based on average estimated conditions.
2. Flow rate, TDH, pump efficiency and motor efficiency based on preliminary plant water manufacturer data sheet provided by design engineer.
3. Power draw determined using pump efficiency equation.
4. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Summary of Savings

A summary of the annual savings associated with this measure are presented in the table below.

Table 24. Plant Water System – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e$/yr)
Base	783,360	$86,953	260.7
Proposed	391,680	$43,476	130.4
Savings	**391,680**	**$43,476**	**130.4**

Notes:

1. Cost savings based on unit cost of $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Conclusion

Reducing the pressure set point for the pumps from 160 to 80 psi significantly reduces the energy use required to produce the same flow. The existing aged pumps may not be operating as efficiency as possible, replacing them with newer, more efficient pumps will assist in maximizing pumping capabilities while minimizing energy use. The plant water system provides water for various processes throughout the WWTF, while not directly related to the NPDES permit requirement, this system assists the proper optimization and operation of other systems such as chemicals, clarifiers, and sludge processing. Having a local plant water system also reduces reliance on using potable water for operation of these processes, which also reduced overall GHG and energy for treating and sending potable water to the plant.

#8 Odor Control System VFD

The Taunton WPCF currently has a chemical scrubber odor control system where the fans would operate at a constant speed continuously. In the comprehensive upgrade design, a new odor control system is proposed to replace the existing system. The proposed system is a wood chip biofilter with three fans sending odorous air from the headworks, gravity thickeners, and solids handling areas. The headworks area will have one 5 HP fan, the solids handling area will have one 10 HP fan, and the gravity thickeners area will have one 15 HP fan. The fans are proposed to be operated on VFDs, which will modulate the speed of the fan based on outside air temperature and building occupancy. Operating the odor control fans on VFDs with an automated control sequence to reduce fan speed will result in energy savings. The energy savings are quantified in the following sections.

Base Case

Under the base case, the odor control fans operate at a constant speed continuously. The manufacturers fan performance curves provided by the design engineer were used to determine the energy usage of the fan under this condition. The following table outlines the base case energy usage.

Table 25. Odor Control Fans – Base Case Energy Usage

Location	Condition	Flow (cfm)	BHP	Motor Efficiency (%)	Power Draw (kW)	Annual Hours of Operation	Annual Energy Use (kWh/yr)	Annual GHG Emissions (mtCO2e/yr)
Headworks	Constant Speed	2,000	3.3	89%	2.8	8,760	24,124	8.03
Solids Handling	Constant Speed	4,000	8.7	92%	7.0	8,760	61,701	20.54
Gravity Thickeners	Constant Speed	4,400	10.5	92%	8.6	8,760	75,170	25.02
						Total	**160,995**	**53.59**

Notes:

1. BHP based on information from manufacturers technical data sheet.
2. Motor efficiency assumed based on premium efficiency standards.
3. Annual hours of operation based on information from design engineer about typical system operation.
4. GHG savings based on the MA emissions rate of 733.8 lbs CO2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Proposed Case

For the proposed case, the speed of the odor control fan is controlled by a VFD. The speed is reduced based on the outside air temperatures. Under NFPA 820 ventilation guidelines, twelve (12) air changes per hour are required for Class 1, Division 1 and 2 areas. The standards, however, allow for a decrease to six (6) air changes per hour during times when the outside air temperature is below 50° F and the facility is unoccupied. The facility must have the ability to increase the air flow, however, when the areas become occupied and when gas detection sensors indicate the need for additional air changes.

To estimate the electrical savings associated with this measure, the following assumptions were made:

- Full speed fan operation during occupied hours. For the headworks and gravity thickener locations, the anticipated occupied time is approximately 1 hour per day, 7 days per week. For the solids handling location, the estimated occupied time is 8 hours per day, 5 days per week. The remaining time in the year is assumed to be unoccupied and half of the unoccupied time was assumed to be under 50 degrees Fahrenheit. When the space is unoccupied, and the outdoor temperature is below 50 degrees Fahrenheit the fan will run at a reduced speed.
- The reduced power consumption using a VFD was calculated using the affinity fan laws. The calculation was based on the squared (instead of the cubed law) to adopt a conservative approach.

The proposed case energy usage is summarized in the following table.

Table 26. Odor Control Fans – Proposed Case Energy Usage

Location	Condition	% of Time	Flow (cfm)	Motor Eff.	VFD Eff.	Power Draw (kW)	Annual Hours of Operation	Annual Energy Use (kWh/yr)	Annual GHG Emissions (mtCO2e/yr)
Headworks	VFD Operation	38%	1,000	89%	97%	0.7	3,340	2,444	0.81
		62%	2,000	89%	97%	2.8	5,420	15,388	5.12
Solids Handling	VFD Operation	48%	2,000	92%	97%	1.9	4,224	7,905	2.63
		52%	4,000	92%	97%	7.3	4,536	32,937	10.96
Gravity Thickeners	VFD Operation	48%	2,200	92%	97%	2.3	4,224	9,631	3.21
		52%	4,400	92%	97%	8.8	4,536	40,127	13.36
							Total	**108,432**	**36.09**

Notes:
1. Motor efficiency from premium efficiency standards.
2. VFD efficiencies assumed based on typical thermal losses.
3. kW accounts for motor and VFD efficiencies.
4. kW was calculated based on Power 2 = Power1 * $(CFM2/CFM1)^2$ / (VFD Efficiencies).

Summary of Savings

A summary of the annual savings associated with this measure are presented in the table below.

Table 27. Odor Control Fans – Energy and GHG Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions ($mtCO_2e/yr$)
Base	160,995	$17,870	53.59
Proposed	108,432	$12,036	36.09
Savings	**52,563**	**$5,834**	**17.50**

Notes:
1. Unit cost is $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO2e/MWh from EPA's eGRID 2018 summary table for Massachusetts.

Conclusion

The proposed operation of the odor control system utilizes VFDs to reduce energy use and provide greenhouse gas savings while also maintaining safe working conditions for the plant personnel. The odor control fans remove potentially harmful and explosive gas from working areas, the VFDs are programmed to automatically change operation based on environmental conditions, this allows the maximum amount of energy savings while also maintaining safety requirements based on NFPA 820. The odor control system does not directly impact the NPDES permit, however, creating safe working conditions, and controlling odors, allows continued operation of the plant to meet NPDES permit requirements.

#9 Premium Efficiency Motors

The United States Department of Energy (DOE) implemented a National Electrical Manufacturer Association (NEMA) Premium Efficiency Rule as of June 1, 2016 and required newly manufactured 1 to 500 hp industrial electrical motors to meet NEMA Premium efficiency standards. However, any motors manufactured prior to June 1, 2016 can be sold if they are still available in warehouses. Based on information provided by the design engineer, all motors included in the comprehensive upgrade design will be specified as premium efficiency motors. Before the DOE NEMA Premium Efficiency Rule, motors used for water and wastewater industry applications were not subject to federal regulation. Therefore, the existing motors at the Taunton WWTF are likely standard efficiency motors with lower efficiencies. The motors replaced during the upgrade will likely result in increased motor efficiency by at least several efficiency points, therefore, reducing energy usage and GHG emissions.

#10 Variable Frequency Drives (VFDs)

VFDs are commonly used to vary the motor speed on pieces of equipment that do not require full power. The comprehensive preliminary design includes installation of VFDs on equipment where varying the speed may result in energy savings and GHG mitigation. Typically, wastewater treatment equipment is sized to reflect the maximum flow condition., This frequently results in equipment that is oversized for average day flow conditions encountered at the plant for the majority of the year. It is possible to reduce this energy intensity for some processes, with the installation of VFDs.

The following pieces of equipment will be operated on VFDs in the proposed comprehensive design:

1. Primary Sludge Pumps
2. Internal Recycle Pumps
3. Return Activated Sludge (RAS) Pumps
4. Waste Activated Sludge (WAS) Pumps
5. Scum Pump
6. Odor Control Fans

It should be noted that installing VFDs on all equipment will not necessarily provide energy savings. VFDs convert frequency and voltage of the supply electricity from AC to DC power to increase and decrease the speed of the motor based on frequency, this conversion consumes energy through thermal losses in the VFD. For modern VFDs, this thermal loss is approximately 3% at full load, which reduces the overall efficiency of the system. If the VFD is not being used to vary the speed of the equipment to conserve energy, then the 3% efficiency loss should be considered in whether a VFD should be installed.

The equipment on VFDs presented above is based on the preliminary design for the comprehensive upgrade at the WWTF, this does not necessarily reflect the final design of the project.

#11 Building Systems – HVAC & Lighting

The proposed comprehensive upgrades include minimal modifications to the lighting and heating, ventilation, and air conditioning (HVAC) equipment throughout the facility. The facility has previously conducted replacements to the lighting systems through the majority of the plant with light emitting diodes (LEDs).

Based on the previous energy balance conducted by JKMuir, it was determined that the building systems make up less than 1% of the overall energy use for the facility (0.77%). The overall energy use of these systems was calculated to be approximately 30,000 kWhs and accounts for approximately 10 mtCO_2e annually. This includes exhaust fans, air handling units, hot water heaters, boilers, and interior and exterior lighting. Of this less than 1%, the majority may be attributed to the HVAC systems. The proposed design of these elements is anticipated to be determined through more detailed design phases. The following table presents the estimated impact of the lighting and HVAC systems at the Taunton WWTF.

Table 28. Energy Impact of Building Systems

	Estimated Total Horsepower (HP)	Estimated Annual Energy Usage (kWh/yr.)	Estimated Annual GHG Emissions (mtCO_2e/yr)
Lighting	0.05	7,500	2.50
HVAC	27.65	22,595	7.52
	Total	**30,095**	**10.02**

Notes:

1. A loading factor of 80% was assumed.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO_2e/MWh from EPAs eGRID 2018 summary table for Massachusetts.

For the purposes of this evaluation, some broad assumptions were made to determine the energy and GHG impact of these proposed improvements. Since the lighting was previously upgraded, lighting was assumed to remain at the current consumption. The following table presents estimates of the energy and GHG impact of reducing energy use of the HVAC system by 5 to 20%.

Table 29. Building Systems Energy Impact – Potential Percent Reduction

Percent Reduction for HVAC	Total Estimated Annual Energy Usage (kWh/yr.)	Total Estimated Annual GHG Emissions (mtCO_2e/yr)
5%	28,965	9.64
10%	27,835	9.27
15%	26,706	8.89
20%	25,576	8.51

Based on these estimates of potential energy reduction, a 20% reduction in energy use of the HVAC systems will still consume nearly 26,000 kWhs and contribute 8.5 mtCO2e on an annual basis.

APPENDIX A

Existing Equipment Curves & Data Sheets

3.4 PRIMARY SETTLING TANKS

3.4.1 Purpose

To remove the settleable portion of suspended solids from the wastewater. Scum that floats on the surface is also removed. A detailed discussion of the theory and process control of this process is contained in *Section 3.4.6.*

3.4.2 Equipment and Components

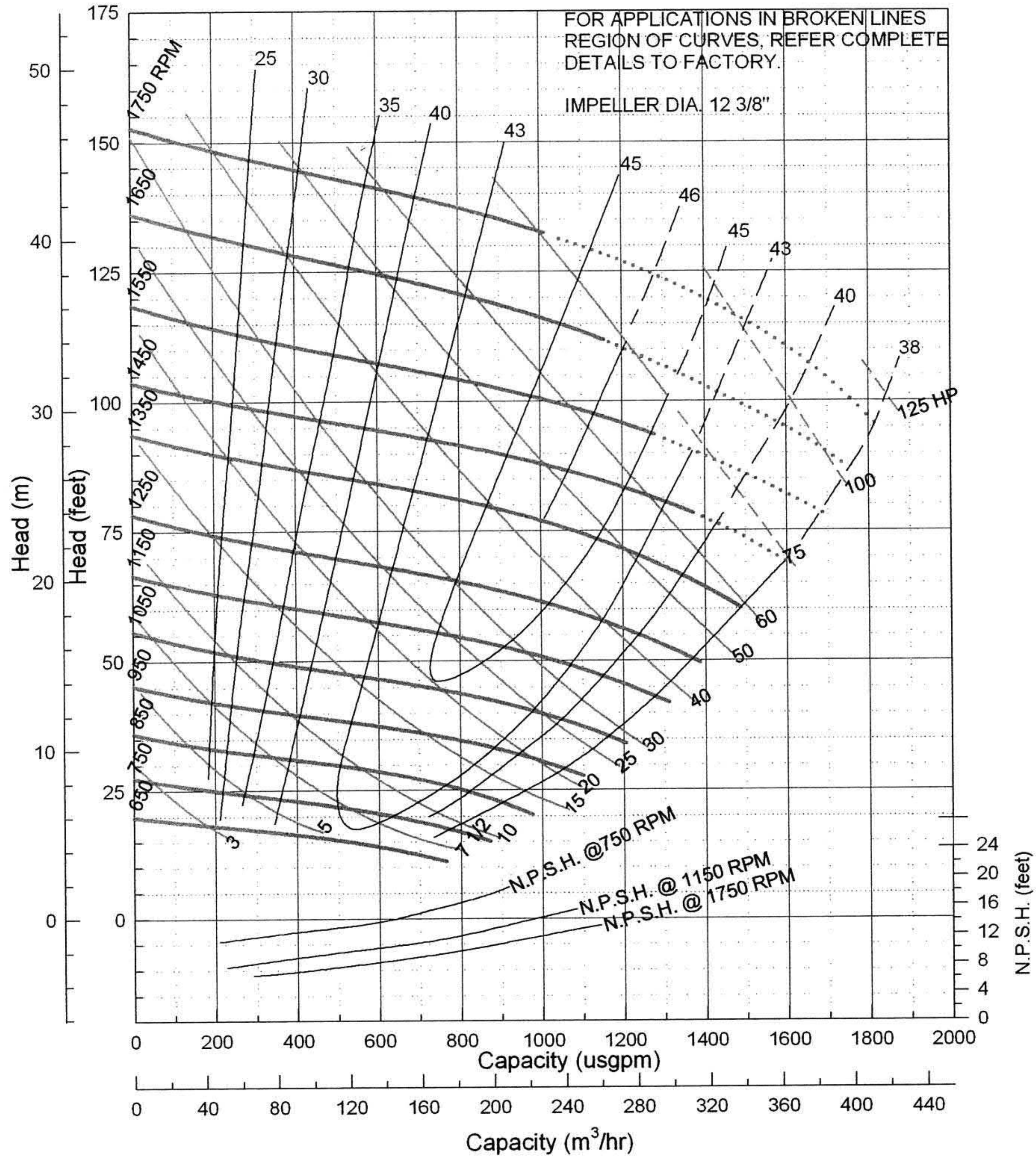
Figure 3.4-1 shows a schematic plan for these facilities.

Primary Settling Tanks						
Tag No.	# of Units	Diameter Feet	Side Water Depth Feet	Surface Overflow Rate GPD/ft^2	Sludge Collectors	
					Type	Diameter
1,2,3	3	55	9	919	Center Pivot	55

Sludge Pumps									
Tag No.	# of Units	Type	Manufacturer	Capacity GPM	Seal	Motor Data			
						HP	Rpm Max	Encl Type	Drive
PS-5001, PS-5002, PS-5003	3	Recessed Impeller	Torus, Model XR4-12	400 @ 50'	Packing	25	1800		Belt Driven, Constant Speed

Scum Pump									
Tag No.	# of Units	Type	Manufacturer	Capacity GPM	Seal	Motor Data			
						HP	Rpm Max	Encl Type	Drive
PS-5004	1	Recessed Impeller	Torus	50 @ 40' TDH	Packing	5	1800		Belt Driven, Constant Speed

Primary Pumps



HAYWARD GORDON LTD.	MODEL	SIZE		CURVE	REV.
	XR4-12	4 x 6 x 12		005-10570	2
Performance Curves TORUS Pumps	DATE	DRN	MAX SPHERE	SPEED	IMP.EYE AREA
	7.03.96	J.M.	4"	VARIABLE	19.1"^{2}

march '06

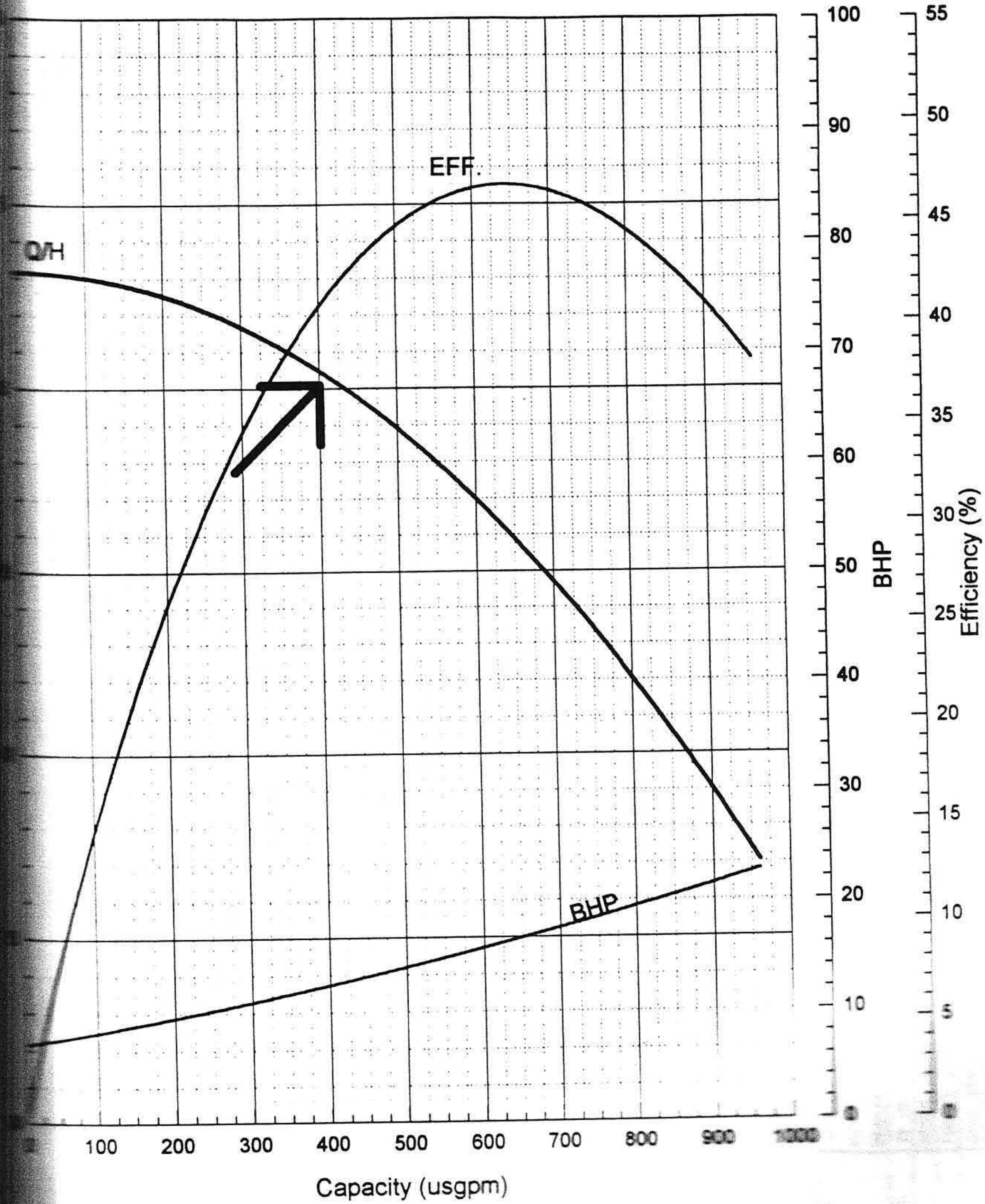
HAYWARD GORDON LTD.

Customer:	*Poole and Kent New England Inc.*	Model:	*XR4-12*
Project:	*City of Taunton WWTF*	Size:	*4 X 6 X 12*
Cust. P.O.:	*98905-1007*	Speed:	*1030 RPM*
Tag #:	*PRIMARY SLUDGE PUMP PSP-3*	Trim Dia.:	*Full*
Curve #:	*278997-3*	Rated Cap.:	*400 USGPM*
Test #:	*1*	Rated Head:	*50 Ft TDH*
Date:	*May 31, 1999*	Drawn:	*G.S./C.M.*

Certified Test by:

P.L. June 1/99

Initial Date



V BELT

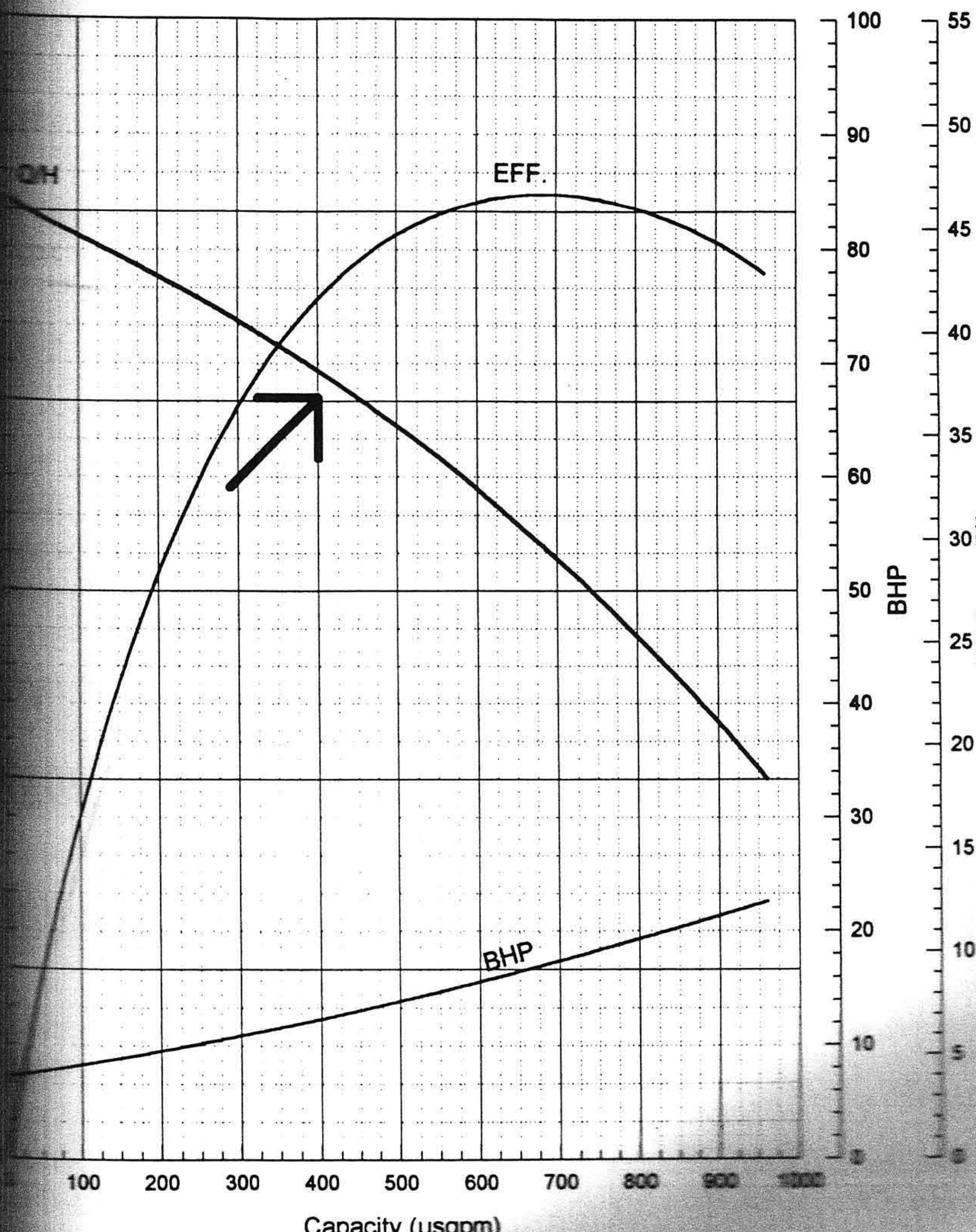
HAYWARD GORDON LTD.

Customer:	Poole and Kent New England Inc.	Model:	XR4-12
Project:	City of Taunton WWTF	Size:	4 X 6 X 12
Cust. P.O.:	98905-1007	Speed:	1030 RPM
Tag #:	PRIMARY SLUDGE PUMP PSP-2	Trim Dia.:	Full
Curve #:	278997-2	Rated Cap.:	400 USGPM
Test #:	1	Rated Head:	50 Ft TDH
Date:	May 31, 1999	Drawn:	G.S.

Certified Test by:

R.L. June 1/99

Initial Date



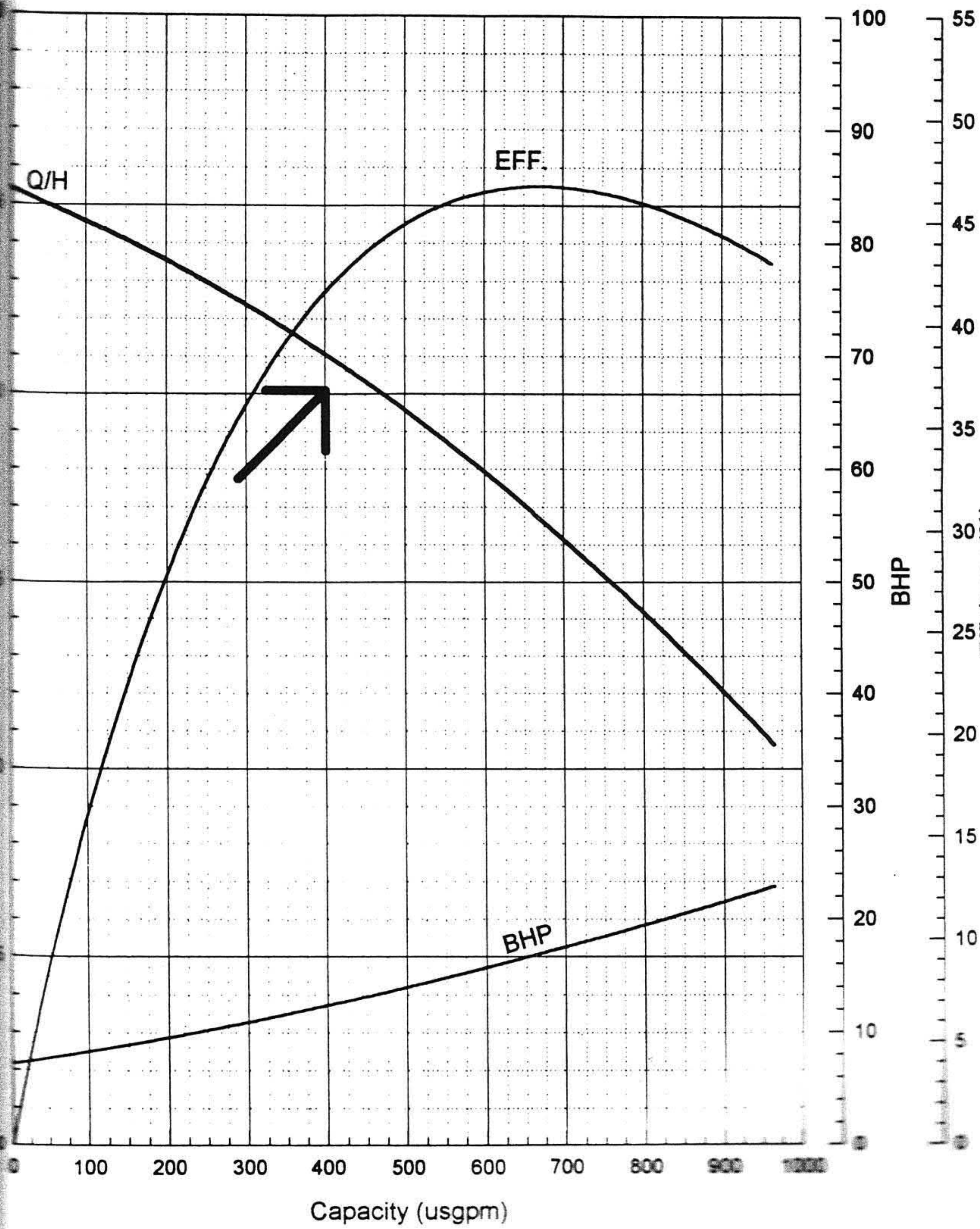
HAYWARD GORDON LTD.

Customer:	*Poole and Kent New England Inc.*	Model:	*XR4-12*
Project:	*City of Taunton WWTF*	Size:	*4 X 6 X 12*
Cust. P.O.:	*98905-1007*	Speed:	*1030 RPM*
Tag #:	*PRIMARY SLUDGE PUMP PSP-1*	Trim Dia.:	*Full*
Curve #:	*278997-1*	Rated Cap.:	*400 USGPM*
Test #:	*1*	Rated Head:	*50 Ft TDH*
Date:	*May 31, 1999*	Drawn:	*G.S.*

Certified Test by:

J.L. June 1/99

Initial *Date*

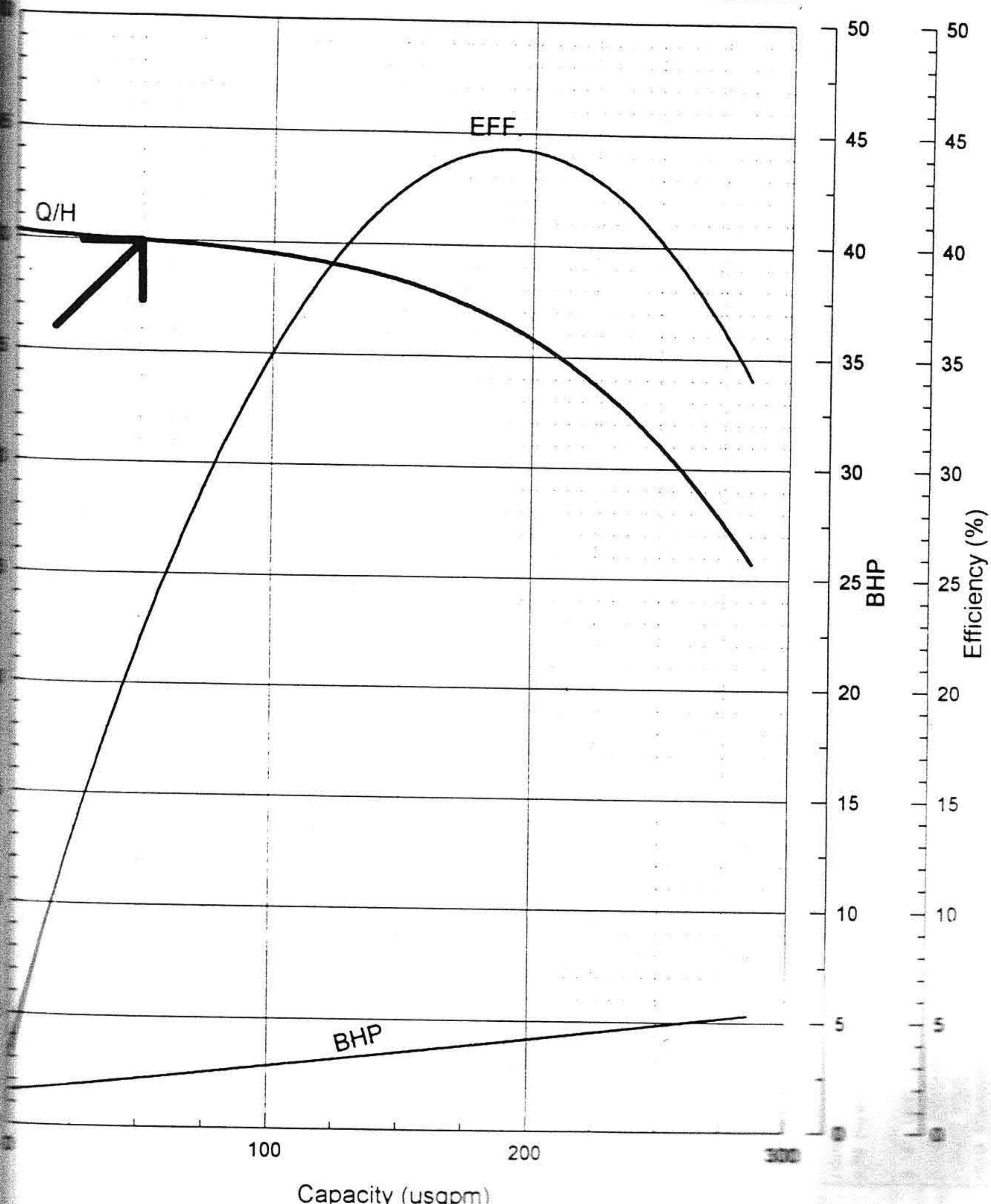


HAYWARD GORDON LTD.

Customer:	Poole & Kent-New England Inc	Model:	XR2-7
Project:	City Of Taunton WWTF	Size:	2X3X7
Cust. P.O.:	98905-1007	Speed:	1580 RPM
Tag #:	Scum Pump	Trim Dia.:	Full Size
Curve #:	278998	Rated Cap.:	50 USGPM
Test #:	1	Rated Head:	40 Ft TDH
Date:	May, 20, 1999	Drawn:	C.M.

Certified Test by:

MAY 21, 1999 — Initial — Date



V BELT

3.7 BLOWERS

3.7.1 Purpose

To provide compressed air to diffusers in Aeration Tank 3 in Battery 1and Aeration Tank 6 in Battery 6. The compressed air diffused into these tanks provides mixing and dissolved oxygen for the process.

3.7.2 Equipment and Components

Figure 3.7-1 shows a schematic plan for these facilities.

BLOWERS

Tag No.	# of Units	Location	Type	Manufacturer	Capacity SCFM	Motor Data			
						HP	Rpm Max	Encl Type	Drive
B-1, 2, 3	3	Blower Building	Mult-Stage <<Rotary Lobe>>	Lamson Model 057-0-C-G-AD	1,600 @ 9 PSIG'	100	3600	ODP	Direct

AIR FLOW CONTROLLERS

Tag No.	# of Units	Function	Battery	Type	Manufacturer	Size
FIT-841	1	Air Flow Meter to Aeration Tank 3	1			
	1	Air Flow Meter to Aeration Tank 6	1			
FIT-842	1	Air Flow Control Valve to Aeration Tank 6	1			
	1	Air Flow Control Valve to Aeration Tank 6	1			

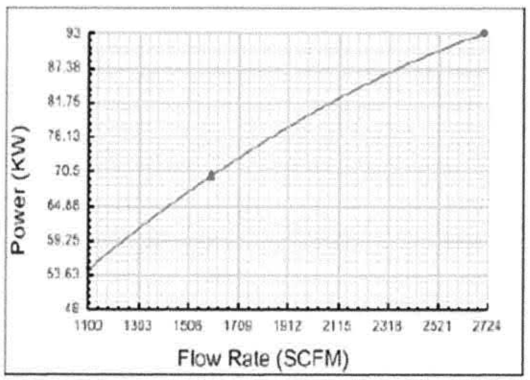
Blower #2

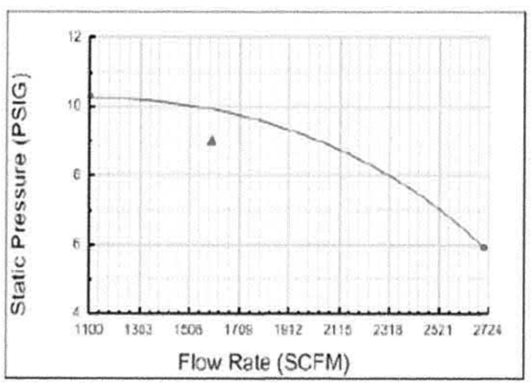
Performance Curve Comparison

Inlet Throttling Curves

Legend for Inlet Conditions

#1 #2 #3 #4 STD

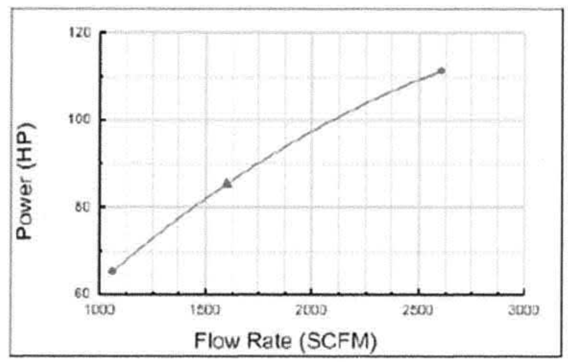


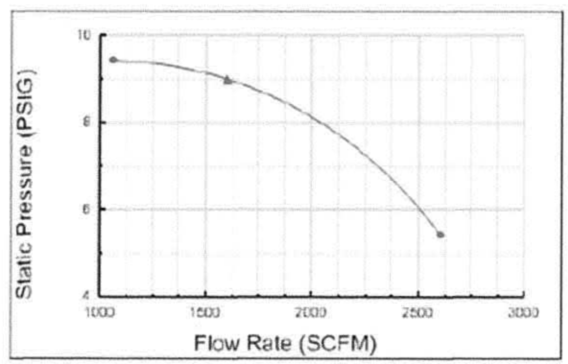


VFD Performance Curves

Legend for Inlet Conditions

#1 #2 #3 #4 STD





Blower #2

SITE AUDIT COST SAVINGS (EXAMPLE)

Inlet Throttling Costs

Scour Air Energy Costs -- With Inlet Valve Throttling				
Month	Days/Month	Daily Energy Usage (kWh/day)	Electric Rate ($/kWh)	Energy Cost ($/month)
January	31	26,384	$0.0747	$ 61,097
February	28	26,384	$0.0747	$ 55,184
March	31	26,384	$0.0747	$ 61,097
April	30	26,384	$0.0747	$ 59,126
May	31	27,206	$0.0747	$ 63,001
June	30	27,206	$0.0747	$ 60,968
July	31	27,206	$0.0747	$ 63,001
August	31	27,206	$0.0747	$ 63,001
September	30	27,206	$0.0747	$ 60,968
October	31	27,206	$0.0747	$ 63,001
November	30	26,384	$0.0747	$ 59,126
December	31	26,384	$0.0747	$ 61,097
TOTAL ANNUAL COSTS				$ 730,666

VFD Operating Cost

Energy Costs -- With 2 VFD's				
Month	Days/Month	Daily Energy Usage (kWh/day)	Electric Rate ($/kWh)	Energy Cost ($/month)
January	31	23,604	$0.0747	$ 54,660
February	28	23,604	$0.0747	$ 49,371
March	31	23,604	$0.0747	$ 54,660
April	30	23,604	$0.0747	$ 52,897
May	31	24,681	$0.0747	$ 57,155
June	30	24,681	$0.0747	$ 55,311
July	31	24,681	$0.0747	$ 57,155
August	31	24,681	$0.0747	$ 57,155
September	30	24,681	$0.0747	$ 55,311
October	31	24,681	$0.0747	$ 57,155
November	30	23,604	$0.0747	$ 52,897
December	31	23,604	$0.0747	$ 54,660
TOTAL ANNUAL COSTS				$ 658,386

3.6 SECONDARY SETTLING TANKS

3.6.1 Purpose

To remove settleable solids from the mixed liquor aerated in the aeration tanks. The resulting sludge is returned to the aeration tanks with a portion wasted to solids treatment. A detailed discussion of the theory and process control of this process is contained in *Section 3.5.6.*

3.6.2 Equipment and Components

Figure 3.6.1 shows a schematic plan for settling tanks in Battery 1, and *Figure 3.6-2* shows a schematic plan for settling tanks in Battery 2.

Secondary Settling Tanks						
Tag No.	Battery	Diameter Feet	Side Water Depth Feet	Surface Overflow Rate GPD/ft^2 at Design	Sludge Collectors	
					Type	Diameter
1A	1	100	12	450	Center Pivot	100
1B	1	100	12	450	Center Pivot	100
2A	2	100	12	450	Center Pivot	100
2B	2	100	12	450	Center Pivot	100

Return Activated Sludge Pumps										
Tag No.	# of Units	Battery	Type	Manufacturer	Capacity GPM	Seal	Motor Data			
							HP	Rpm Max	Encl Type	Drive
RS-1001 RS-1002	2	1	Recessed Impeller	Fairbanks-Morse	2,200 @ 35'	Mech.	25	700		Variable Speed-VFD
RS-2001 RS-2002 RS-2003	3	2	Recessed Impeller	Fairbanks-Morse	2,900 @ 35'	Mech.	30	700		Variable Speed-VFD

It is of the utmost importance for the treatment plant operators to be aware of, and prevent any chance of, a cross connection in the potable water supply. A cross connection is a direct connection between a wastewater source and a potable water supply. Under normal circumstances the potable water is under high pressure and there is no chance of sewage getting into the water line, but under emergency conditions, such as a fire or a water main break, water pressure may drop to zero or even become negative, causing a suction which may draw the sewage into the water line. The classic example of a cross connection occurs when a flexible hose is connected to an open faucet and the loose end of the hose is sitting in the water—filled basin in which equipment contaminated with sewage is being washed. A large demand on the water system causes a negative pressure and the sewage is drawn up through the hose and into the water main. It is noted that in a situation such as this, any safety device would have to fail completely for this to occur. Yet the operator should be aware that it is a possibility.

Operators should not allow hoses used in potable water wash down operations to dangle in tanks or be placed in a position where they might be submerged if the tank water level should rise.

Plant Water System

A non-potable (i.e. that which is not fit for human consumption) water system is supplied from the chlorine contact tank to various parts of the treatment plant as follows:

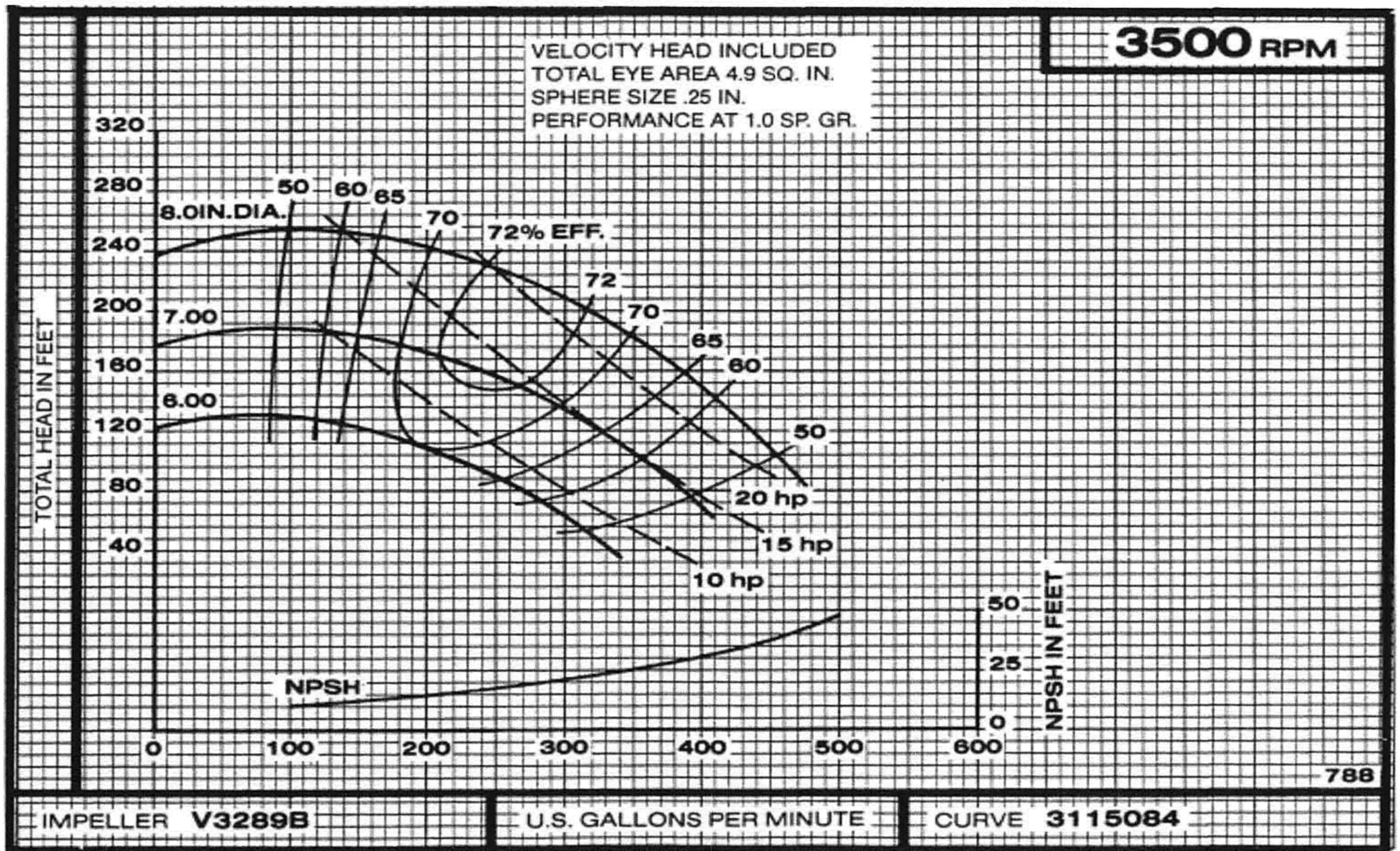
- Yard hydrants
- Pump seal water
- Lime slurry make-up water
- Thickener dilution water
- Flushing water

The plant water system is shown in *Figure 3.11-1* and includes the following:

- One, 470 gpm @ 230 feet TDH
- One, 250 gpm @ 230 feet TDH
- Pressure regulating valves.
- Pump control panel with HAND-OFF-AUTO switches, running lights, low system and low suction alarm lights. In AUTO the pumps operate to maintain system pressure at 100 psi. In HAND the pump(s) operate continuously.
- A strainer for removal of fine solids in the plant effluent.

Pump #1
Peerless - C820AM - 25 HP - 3500 RPM
Pump #2
Peerless - C1125AM - 40 HP - 3500 RPM

Plant watere Pumps



Page 8 Rev. 7-88

Plant water pumps

Pump #1 25 HP - 250 GPM @ 230 TDH

Pump #2 40 HP – 470 GPM @ 231 TDH

Carlsen Systems, LLC

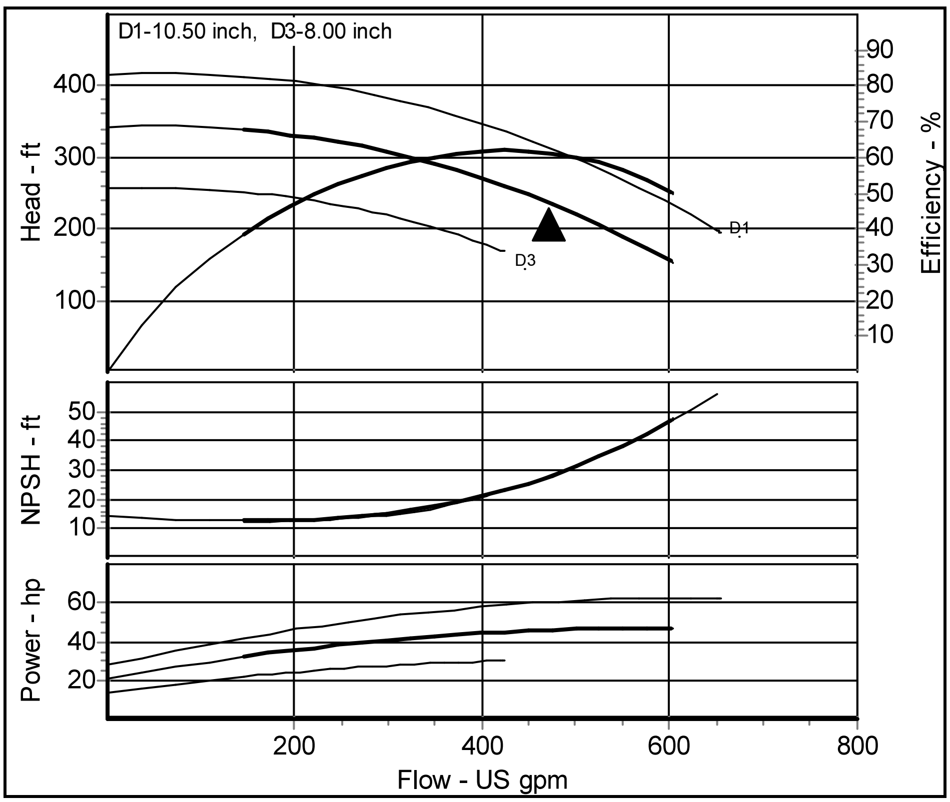
Craig Burmeister
Phone 203-427-3375

Customer :

Contact :

Project :			**Phone :**	**Fax :**
Quote No. :	US-1585-63	**Page No :** 1	**Date :**	Tuesday, November 28, 2017

Type:	**C - End Suction Close Coupled General Purpose**	Item :	**1**
Pump Model:	**Peerless - C1125**	Impeller No.:	SeePtslist
Nom. Speed:	**3500 RPM, 60 Hz Electric**	Fluid:	**Water**
Impeller Dia.:	**9.54** inch	Temperature:	**68** °F
Curve No.:	**3110005/Rev 3**	Viscosity:	**1.007** cSt
Market :	**Water**	Sp. Gravity:	**1.000**
		Your Ref. :	



Duty Flow	**470**	US gpm
Duty Head	**230**	ft
Imp. Dia.	**9.54**	inch
Power Required	**45.9**	hp
NPSH Required	**27.7**	ft
Efficiency	**61.3**	%
Peak Power	**46.8**	hp
Closed Valve Head	**342.2**	ft
Tolerance	**Hyd Ins 14.6 Unilateral**	

Comments

Performance curve represents typical performance. See Hydraulic Performance document in RAPID for perfomance test acceptance grades/tolerances & contractual guarantees..

Flow (US gpm)	**Head (ft)**	**Efficiency (%)**	**Power Required (hp)**	**NPSH Required (ft)**
145.0	338.8	38.7	32.1	12.6
202.0	330.7	47.2	35.7	12.9
259.0	318.7	53.7	38.8	14.0
315.9	302.5	58.3	41.4	16.0
372.9	282.0	61.0	43.5	19.1
429.9	257.1	61.9	45.1	23.6
486.9	227.7	60.7	46.2	29.6
543.9	193.7	56.9	46.7	37.3
600.8	154.8	50.2	46.8	47.0

Centrifuge Sludge Pumps
model - 40-6LTNS

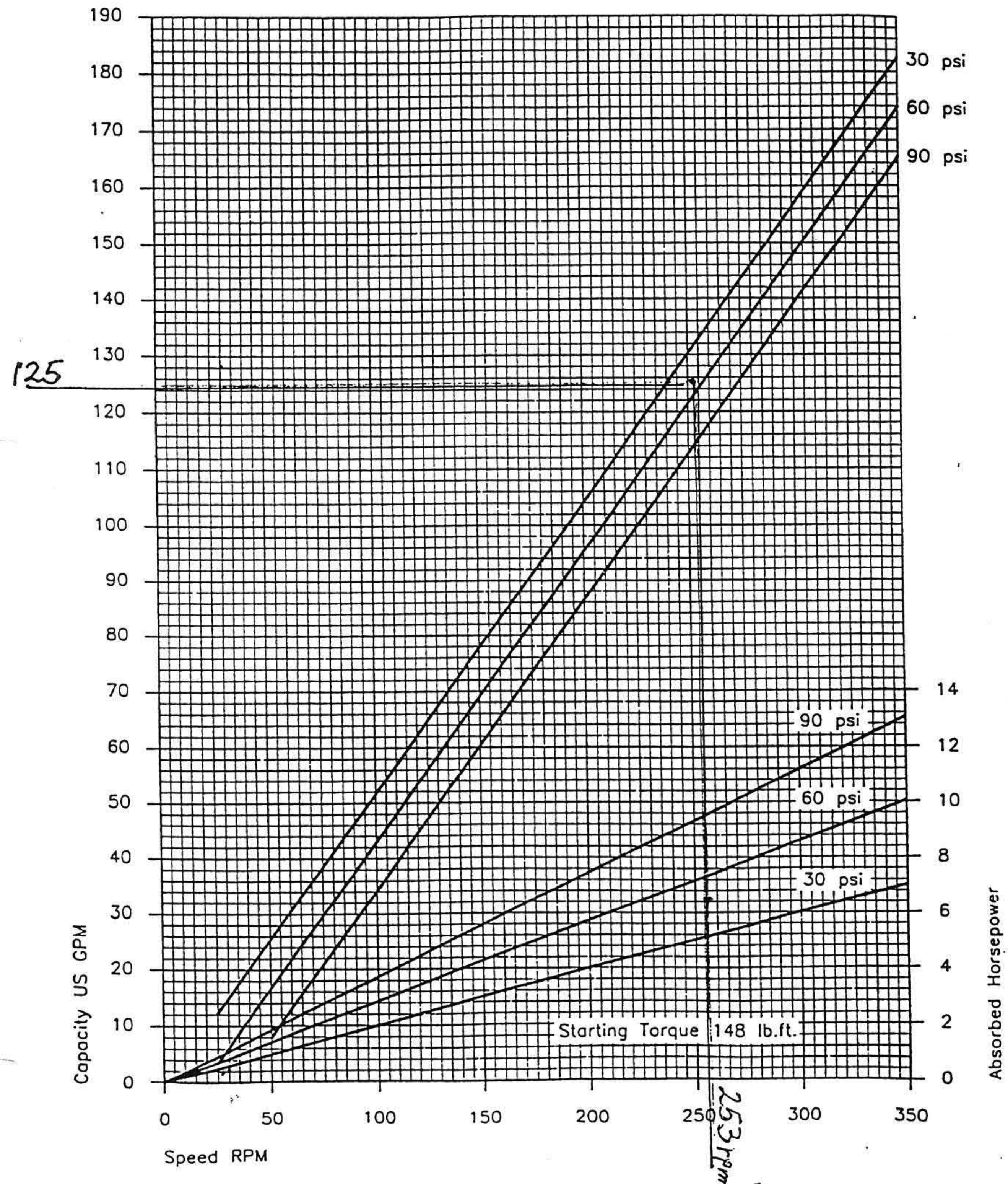
seepex
Inc.

seepex
Inc.
1834 Valley Street
Dayton, Ohio 45404
USA
Phone (513) 233-9904
Fax (513) 233-9024

PERFORMANCE CURVE

CITY OF TAUNTON, MA.
125 GPM AT 43 PSI

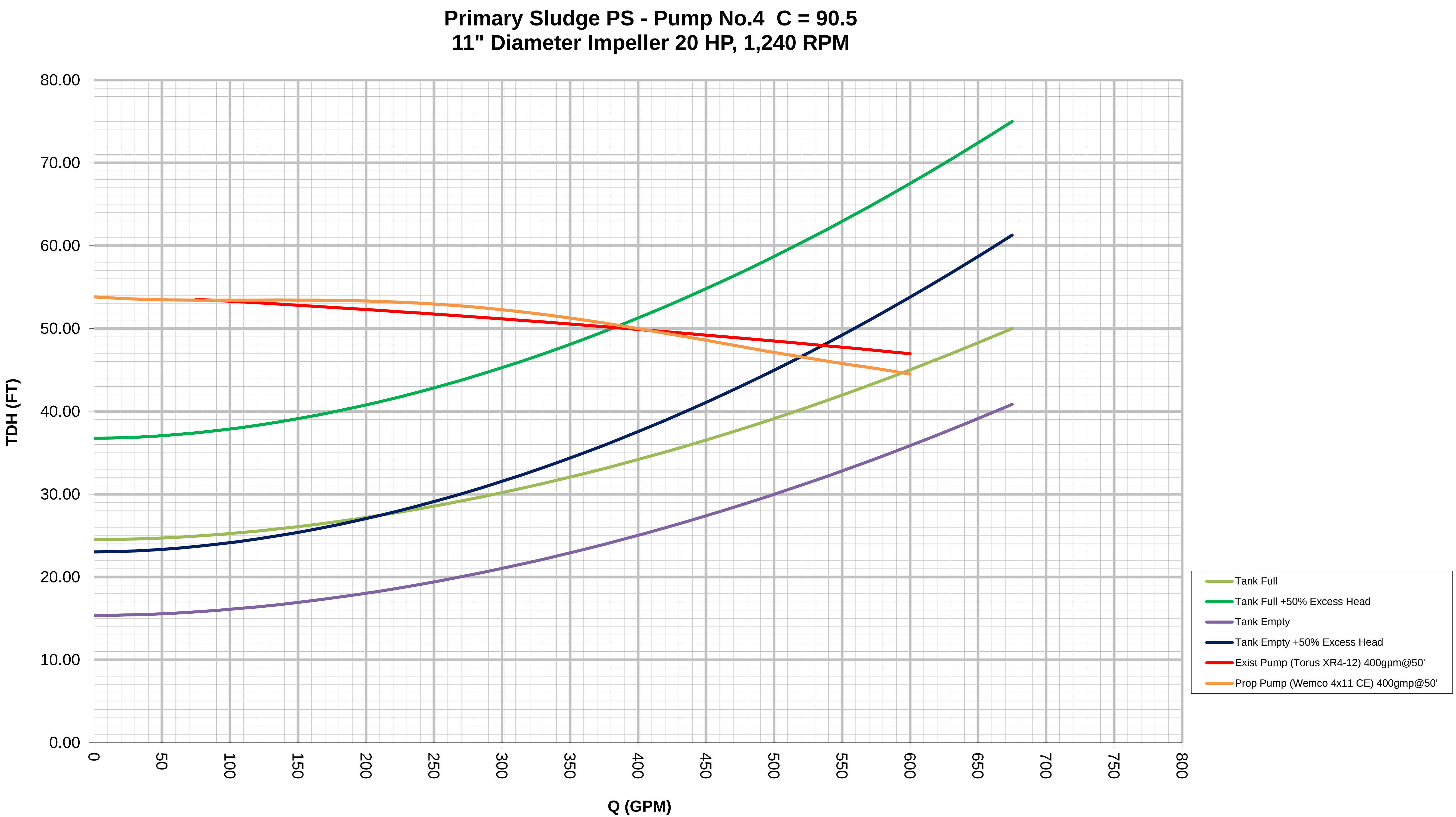
40–6LT



Values based upon water 68°F : For notes on drive selection refer to PER

APPENDIX B

Proposed Equipment Curves & Data Sheets


Primary Sludge PS - Pump No.4 C = 90.5
11" Diameter Impeller 20 HP, 1,240 RPM
TDH (FT)
Q (GPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Tank Full
Tank Full +50% Excess Head
Tank Empty
Tank Empty +50% Excess Head
Exist Pump (Torus XR4-12) 400gpm@50'
Prop Pump (Wemco 4x11 CE) 400gmp@50'

Proposed Aeration Blower Power Draw

Extended Performance Table

Outlet pressure psi	Airflow turndown	Temperature (T0) 95 °F Relative humidity (rH): 50%	
		V0 [acfm]	P [hp]
23.202	100%	5357	212.7
23.202	98%	5249	207.7
23.202	60%	3214	128.6
23.202	40%	2143	91.9
23.402	100%	5357	215.1
23.402	98%	5249	210.2
23.402	60%	3214	131
23.402	40%	2143	95.6

Proposed Thickened Sludge Pump

Bredel 65, Bredel 80 and Bredel 100 hose pumps

Bredel SERIES

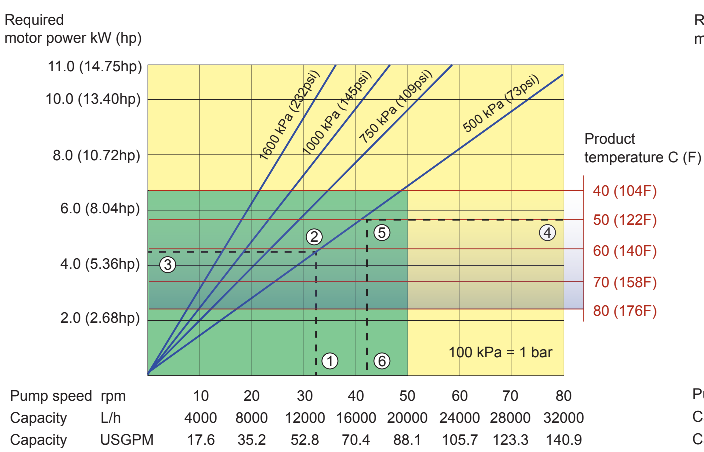
Bredel Hose Pumps

FEATURES AND BENEFITS

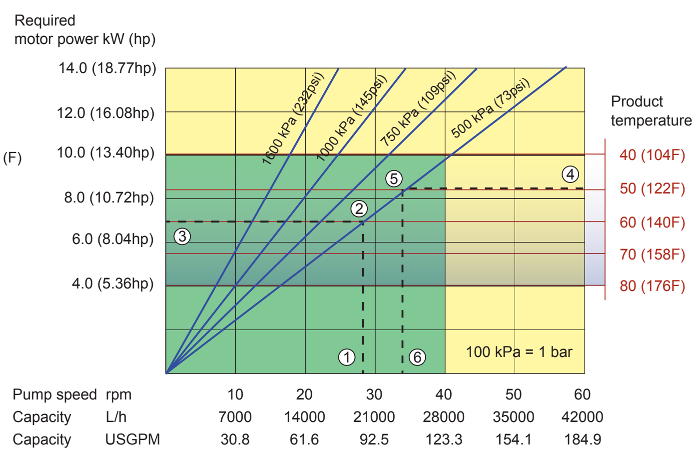
- Sealless, valveless pumping principle for reliable, low maintenance metering, dosing and transfer
- Flow rates up to 53,000 L/hr (233 GPM) and pressures up to 16 bar (232 psi)
- Dry running and self-priming, with up to 9.5 meters (30 foot) suction lift capability
- Robust design for aggressive chemicals or abrasives
- Compact direct coupled design to maximize gearbox life
- Simple hose change decreases cost of ownership, downtime and need for parts inventory

PERFORMANCE

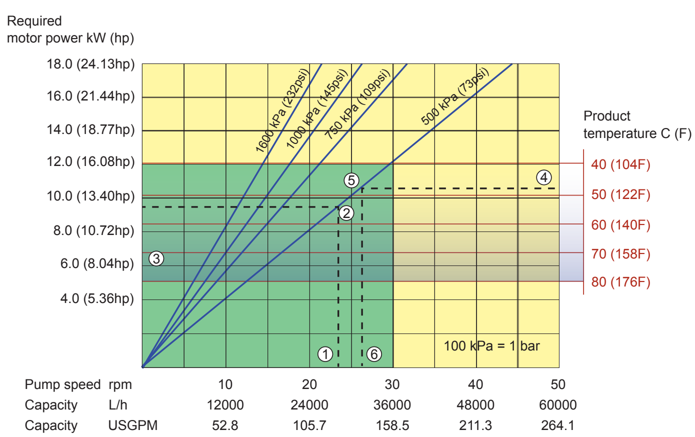
Bredel 65



Bredel 80



Bredel 100



Continuous Duty

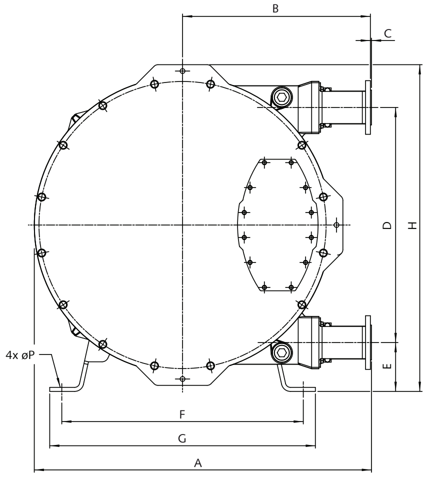
Intermittent Duty*

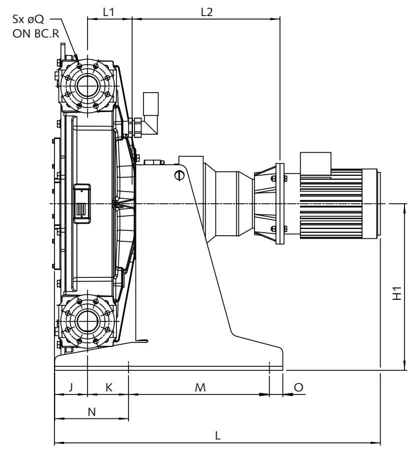
* Maximum 2 hours operation followed by minimum 1 hour stop

1. Flow required indicates pump speed
2. Calculated discharge pressure
3. Net motor power required
4. Product temperature
5. Calculated discharge pressure
6. Maximum recommended pump speed

Note: The area of continuous operation diminishes with increased product temperatures.
For product temperatures >40C (104F), the area of continuous operation is limited by the corresponding red temperature line.

DIMENSIONS





Type	A	B	C	D	E	F	G	H	H1	J	K	Lmax	L1	L2max	M	N	O	ØP	ØQ	R	S
Bredel 65 (mm)	1059	580	3	746	152	680	740	1036	525	104	137	1172	141	486	415	220	50	18	18	145	4
Bredel 65 (inches)	41.7	22.8	0.12	29.4	6	26.8	29.1	40.8	20.7	4.1	5.4	46.1	5.6	19.1	16.3	8.7	2	0.71	0.71	5.7	0.16
Bredel 80 (mm)	1257	700	4	876	182	900	990	1218	620	124	153	1351	166	582	525	275	50	22	18	160	8
Bredel 80 (inches)	49.5	27.6	0.16	34.5	7.2	35.4	39	48	24.4	4.9	6	53.2	6.5	22.9	20.7	10.8	2	0.9	0.71	6.3	0.31
Bredel 100 (mm)	1468	813	3	1042	199	1050	1140	1415	720	151	173	1392	200	489	540	310	50	22	18	180	8
Bredel 100 (inches)	57.8	32	0.12	41	7.8	41.3	44.9	55.7	28.3	5.9	6.8	54.8	7.9	19.3	21.3	12.2	2	0.9	0.71	7.1	0.31

TECHNICAL SPECIFICATIONS

	Bredel 65	Bredel 80	Bredel 100
Flow range	up to 32,000 L/hr (140.9 GPM)	up to 40,000 L/hr (176.1 GPM)	up to 53,000 L/hr (233.4 GPM)
Capacity	6.7 L/rev (1.77 G/rev)	11.7 L/rev (3.09 G/rev)	20 L/rev (5.28 G/rev)
Minimum starting torque	1,150Nm (10,178 inch-lbs)	2,000Nm (17,701 inch-lbs)	3,100Nm (27,437 inch-lbs)
Hose lubricant required	20 liters (5.28 G)	40 liters (10.57 G)	60 liters (15.85 G)
Pumphead weight	398 kg (877 lbs)	672 kg (1482 lbs)	1032 kg (2275 lbs)
Max inlet pressure	2.0 bar (30 psi)	1.5 bar (23 psi)	
Common features			
Suction pressure	0.05 bar (0.73 psi)		
Maximum discharge pressure	1,600 kPa (16 bar) (232 psi)		
Product temperature range*	-10C up to 80C (14F up to 176F)		
Ambient temperature range**	-20C up to 45C (-4F up to 113F)		

*Please consult your Bredel representative for lower or higher temperature operation.
**Allowable ambient temperature is based on pump capabilities and may be further limited by gearbox ambient capabilities

MATERIALS OF CONSTRUCTION

Components	Materials
Pump housing	Cast iron
Rotor	Cast iron
Pressing shoes	Aluminium or epoxy
Cover	Mild steel
Brackets	Galvanized steel or AISI 316
Flanges	Galvanized steel or AISI 316
Inserts	AISI 316, PVC, PP, PVDF
Support frame	Galvanized steel or AISI 316
Hose clamps	Galvanized steel or AISI 316
Shaft	Alloy steel
Seals	Neoprene or nitrile

Options	Features
Available hose materials	NR, NBR, F-NBR, EPDM, CSM
Available flanges	ANSI, EN DIN, JIS
Available inserts	Bredel standard or with sanitary connectors
High level float switch	Max. 2A, 230V AC/DC, max. 40VA
Low level float switch	ATEX: max. 50 mA, max. 28V AC/DC
Integrated FI for stand alone speed control	Factory programmable from 12-80 Hz
Revolution counter	For maintenance intervals and/or metering
Vacuum assist	For difficult suction conditions and high viscosity fluids
Cover lifting device	For one-man pump maintenance

Bredel Hose Pumps

wmpg.com
800-282-8823
support@wmpg.us

Inlet Pulse Accumulator series IPA40, IPA65 and IPA100

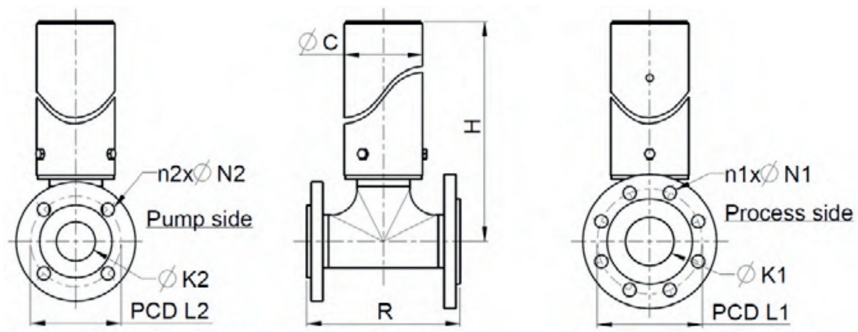
Bredel SERIES
Bredel Hose Pumps

FEATURES AND BENEFITS

- **Reduces positive and negative peaks when inlet conditions vary**
- **Eliminates up to 90% of the pump inlet pulsation**
- **Provides quieter operation and maximises hose life**
- **Low maintenance set-up, suitable for any Bredel and APEX pump with hose size from 25mm (1”) to 100mm (4”)**

Consult your Bredel sales representative for advice on selecting an appropriate Inlet Pulse Accumulator for your application.

DIMENSIONS



Dimensions in mm (for DIN/EN flanges)												
IPA Type	Pump Type		SS	PVC	DIN/EN			DIN/EN			SS	PVC
		C	H	H	K1	L1	n1 x N1	K2	L2	n2 x N2	R	R
IPA40	APEX28	89	402	396	DN40	110	4 x 18	DN25	85	4 x 14	180	190
IPA40	APEX35	89	402	396	DN40	110	4 x 18	DN32	100	4 x 18	180	190
IPA40	Bredel 25	89	402	396	DN40	110	4 x 18	DN25	85	4 x 14	180	190
IPA40	Bredel 32	89	402	396	DN40	110	4 x 18	DN32	100	4 x 18	180	190
IPA40	Bredel 40	89	402	396	DN40	110	4 x 18	DN40	110	4 x 18	180	190
IPA65	Bredel 50	108	511	513	DN65	145	8 x 18*	DN50	125	4 x 18	212	270
IPA65	Bredel 65	108	694	696	DN65	145	8 x 18*	DN65	145	8 x 18*	212	270
IPA100	Bredel 80	140	776	791	DN100	180	8 x 18	DN80	160	8 x 18	276	390
IPA100	Bredel 100	140	931	946	DN100	180	8 x 18	DN100	180	8 x 18	276	390

*4 x 18 on PVC version

Dimensions in inches (for ANSI flanges)												
IPA Type	Pump Type		SS	PVC	ANSI			ANSI			SS	PVC
		C	H	H	K1	L1	n1 x N1	K2	L2	n2 x N2	R	R
IPA40	APEX28	3.5	15.8	15.6	1 1/2	3 7/8	4 x 5/8	1	3 1/8	4 x 5/8	7.1	7.5
IPA40	APEX35	3.5	15.8	15.6	1 1/2	3 7/8	4 x 5/8	1 1/2	3 7/8	4 x 5/8	7.1	7.5
IPA40	Bredel 25	3.5	15.8	15.6	1 1/2	3 7/8	4 x 5/8	1	3 1/8	4 x 5/8	7.1	7.5
IPA40	Bredel 32	3.5	15.8	15.6	1 1/2	3 7/8	4 x 5/8	1 1/4	3 1/2	4 x 5/8	7.1	7.5
IPA40	Bredel 40	3.5	15.8	15.6	1 1/2	3 7/8	4 x 5/8	1 1/2	3 7/8	4 x 5/8	7.1	7.5
IPA65	Bredel 50	4.3	20.1	20.2	2 1/2	5 1/2	8 x 3/4	2	4 3/4	4 x 3/4	8.3	10.6
IPA65	Bredel 65	4.3	27.3	27.4	2 1/2	5 1/2	8 x 3/4	2 1/2	5 1/2	8 x 3/4	8.3	10.6
IPA100	Bredel 80	5.5	30.6	31.1	4	7 1/2	8 x 3/4	3	6	8 x 3/4	10.9	15.4
IPA100	Bredel 100	5.5	36.7	37.2	4	7 1/2	8 x 3/4	4	7 1/2	8 x 3/4	10.9	15.4

TECHNICAL SPECIFICATIONS

	IPA40	IPA65	IPA100
Assembly weight - SS version	9.1kg (20lb)	17.3kg (38lb)	34.5kg (76lb)
Assembly weight - PVC version	3.8kg (8.4lb)	10kg (22lb)	25kg (55lb)
Maximum working pressure on suction line	350kPa, 3.5bar (50psi)		
Ambient temperature	-20C to 45C (-4F to 113F)		
Product temperature	-10C to 80C (14F to 176F)		
Storage temperature	-40C to 70C (-40F to 158F)		
Available hose materials	NR, NBR, EPDM		
Available flanges	EN (DIN), ANSI		

MATERIALS OF CONSTRUCTION

	IPA40, IPA65, IPA100
T-piece and flanges	AISI 316 or PVC
Protection hood	AISI 304
O-ring	NBR

ORDERING CODES AND SELECTION OPTIONS

For ordering please advise:

- Flange size and type
- Pump size and type
- Required material for hose
- Required material for T-piece and flanges

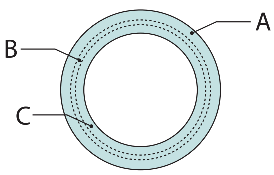
For further information on Inlet Pulse Accumulators please contact your Bredel representative.

Replacement hose element			Part number				
Hose type	**Material**	**Colour code**	**IPA40/25 IPA40/32 IPA40/40**	**IPA65/50**	**IPA65/65**	**IPA100/80**	**IPA100/100**
NR	Natural rubber	Purple	28-IP04004020	28-IP06505020	28-IP06506520	28-IP10008020	28-IP10010020
NBR	Nitrile rubber	Yellow	28-IP04004040	28-IP06505040	28-IP06506540	28-IP10008040	28-IP10010040
EPDM	EPDM	Red	28-IP04004075	28-IP06505075	28-IP06506575	28-IP10008075	28-IP10010075

The material of the inner extruded liner of the hose determines the hose type. Each hose type is marked by a unique colour code.

The IPA hose liner material should be chemically resistant to the product to be pumped.
A matching hose should be selected relative to your application.

A - Outer extruded layer made of natural rubber
B - Two nylon reinforcement layers
C - Inner extruded liner



In-line pulsation dampeners for Bredel 25-100, APEX 28 and APEX 35 pumps

ACCESSORIES

FEATURES AND BENEFITS

Bredel Hose Pumps

- **Increases process uptime and performance by reducing pulsation in pump and process**
- **Reduces discharge pulsation, lessens vibrations and eliminates pipe hammer to improve pump performance**
- **In-line, low maintenance set-up, suitable for any Bredel and APEX pump with hose size from 25mm (1”) to 100mm (4”)**
- **Eliminates up to 90% of the pump discharge pulsation between 2 bar (29psi) and 16 bar (232psi) pressure**
- **Certified to meet directive 2014/68/EU by Lloyds register**

Consult your Bredel sales representative for advice on selecting an appropriate in-line pulsation dampener for your application.

DIMENSIONS

		Dimensions in mm (for DIN flanges)							Dimensions in inches (for 150# ANSI flanges)						
		A	B	C	C	n x N	L	M	A	B	C	C	n x N	L	M
Dampener Type	Pump Type			SS	PVC PVDF PP			DIN flange size			SS	PVC PVDF PP			ANSI flange size
PD40	APEX 28	168	800	4	20	4 x 14	85	25	6.6	31.5	0.16	0.79	4 x 5/8	3 - 1/8	1
PD40	APEX 35	168	800	4	20	4 x 18	100	32	6.6	31.5	0.10	0.79	4 x 5/8	3 - 7/8	1 - 1/2
PD40	Bredel 25	168	800	4	20	4 x 14	85	25	6.6	31.5	0.16	0.79	4 x 5/8	3 - 1/8	1
PD40	Bredel 32	168	800	4	20	4 x 18	100	32	6.6	31.5	0.16	0.79	4 x 5/8	3 - 1/2	1 - 1/4
PD40	Bredel 40	168	800	2.5	20	4 x 18	110	40	6.6	31.5	0.10	0.79	4 x 5/8	3 - 7/8	1 - 1/2
PD65	Bredel 50	245	1056	6	20	4 x 18	125	50	9.6	41.6	0.24	0.79	4 x 3/4	4 - 3/4	2
PD65	Bredel 65	245	1058	3	20	4 x 18	145	65	9.6	41.7	0.12	0.79	4 x 3/4	5 - 1/2	2 - 1/2
PD65	Bredel 265	245	1058	3	20	4 x 18	145	65	9.6	41.7	0.12	0.79	4 x 3/4	5 - 1/2	2 - 1/2
PD100	Bredel 80	324	1356	8	48	8 x 18	160	80	12.8	53.4	0.31	1.89	4 x 3/4	6	3
PD100	Bredel 280	324	1356	8	48	8 x 18	160	80	12.8	53.4	0.31	1.89	4 x 3/4	6	3
PD100	Bredel 100	324	1356	3	48	8 x 18	180	100	12.8	53.4	0.12	1.89	8 x 3/4	7 - 1/2	4
PD100	Bredel 2100	324	1356	3	48	8 x 18	180	100	12.8	53.4	0.12	1.89	8 x 3/4	7 - 1/2	4

TECHNICAL SPECIFICATIONS

Pulsation Dampener	PD/40	PD/65	PD/100
Estimated assembly weight	34.4kg, 75.8lbs	79.9kg, 176.1lbs	146kg, 321.9lbs
Maximum allowable pressure in vessel	1600 kPa (16 bar), 232.1psi		
Maximum working pressure discharge line	1600 kPa (16 bar), 232.1psi		
Ambient temperature of the pulsation dampener	-20C to 45C, -4.0F to 113.0F		
Product temperature for pulsation dampener	-10C to 80C, 14.0F to 176.0F		
Storage temperature of pulsation dampener	-40C to 70C, -40.0F to 158.0F		
Available hose materials	NR, NBR, EPDM, CSM		

Flanges and inserts	PD/40	PD/65	PD/100
Available inserts for flanges	SS, PVC, PP, PVDF	Steel, SS, PVC, PP, PVDF	Steel, SS, PVC, PP, PVDF
Available flanges	DIN, ANSI, JIS standard in galvanized steel, or AISI 316 SS option		

MATERIALS OF CONSTRUCTION

	PD/40, PD/65, PD/100
Housing	Carbon steel, coated according to ISO 12944, class C4
O Rings	NBR
Flange	DIN, ANSI, JIS: galvanized steel, stainless steel 316
Inserts	Steel, SS, PP, PVC or PVDF

* Please contact your Bredel representative for pulsation dampeners in Stainless Steel 316 configuration for increased corrossion resistance.

ORDERING CODES AND SELECTION OPTIONS

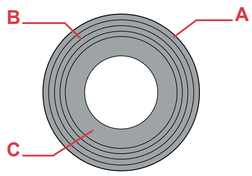
For ordering codes and information on pulsation dampeners and inserts please contact your Bredel representative.

Replacement hose element			Part number		
Hose Type	Material	Colour code	PD/40	PD/65	PD/100
NR	Natural rubber	Purple	28-P040020	28-P065020	28-P100020
NBR	Nitrile rubber	Yellow	28-P040040	28-P065040	28-P100040
EPDM	EPDM	Red	28-P040075	28-P065075	28-P100075
CSM	CSM	Blue	28-P040070	28-P065070	28-P100070

The material of the inner liner of the hose determines the hose type. Each hose type is marked by a unique colour code.

The pulsation dampener hose liner material should be chemically resistant to the product to be pumped.
A matching hose should be selected relative to your application.

A Outer extruded layer made of natural rubber
B Four nylon reinforcement layers
C Inner extruded liner



Bredel Hose Pumps
wmftg.com
+44 (0)1326 370 370
info@wmftg.com

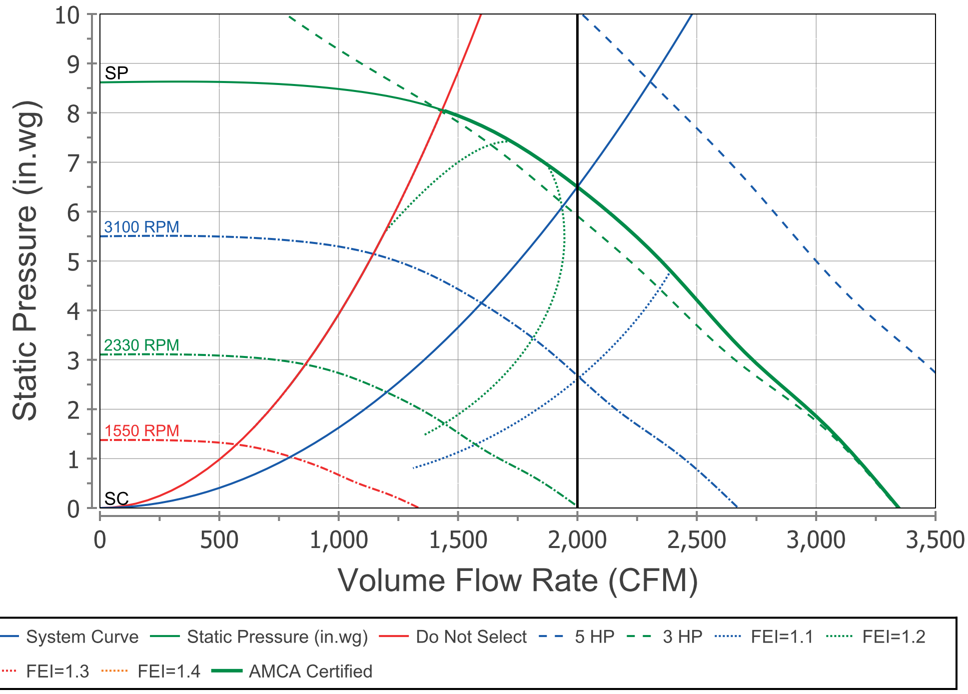
Hartzell AIR MOVEMENT

Proposed Odor Control Fan

Quality • Value • Commitment

Hartzell-FLOW™ v1.0.18 / February 2019

A41P0-122FA100FGFCL3



Fan Tag#:

Vol Flow Rate	2000
Pressure	6.5
Density (lbs/ft³)	0.075
Oper. Temp. (°F)	70
Fan RPM	3880
Max Safe RPM	4521
Operating Power	3.267
Standard Power	3.267
Static Efficiency	0.626
Outlet Velocity (fpm)	2299
Fan Energy Index (FEI)	1.19
Fan Efficiency Grade (FEG)	FEG75

Discharge Sound Power Levels referred to 10^-12 watts

1	2	3	4	5	6	7	8
106	112	106	95	91	88	85	82

Radiated Sound Power Levels referred to 10^-12 watts

1	2	3	4	5	6	7	8
102	105	96	84	79	75	72	69

Radiated Sound is not AMCA Licensed

Hartzell Air Movement certifies that the model shown is licensed to bear the AMCA Seal.
The ratings shown are based on tests and procedures performed in accordance with AMCA publication 211 and AMCA publication 311 and comply with the requirements of the AMCA Certified Ratings Program.
FEI values are calculated in accordance with ANSI/AMCA Standard 208 and are based on four-pole TEFC motors of the size shown.
Power rating BHP excludes transmission losses.
Performance certified is for Installation Type D: Ducted Inlet, Ducted Outlet.
AMCA Licensed for Sound and Air Performance.
Performance ratings do not include the effects of appurtenances (Accessories).
Sound ratings are based on sound level data obtained in accordance with AMCA Standard 300. The sound power level ratings shown are in decibels, referred to 10^-12 watts, calculated per AMCA Standard 301. Fan Outlet Sound Testing. Values shown are for outlet Lwo sound power levels for:
Installation Type D: Ducted Inlet, Ducted Outlet.
Ratings include the effects of duct end correction.

Discharge Sound Pressure = 90 dBA @ 5ft

Radiated Sound Pressure = 81 dBA @ 5ft

Discharge Sound Power = 101 LwA

Radiated Sound Power = 92 LwA

The A-weighted sound pressure level (dBA) is based on Hartzell Laboratory sound power tests, and is calculated in accordance with AMCA standard 303.

The FEG, dBA, LwA and radiated values are not AMCA International Licensed.

The calculation assumes a free field condition with a directivity factor for hemi-spherical radiation (Q=2).

The installed sound pressure levels are influenced by the installation and acoustic environment, and cannot be guaranteed. Use of this estimate level along for field acceptability test is not recommended.

Although the calculation can be done for any stated distance, the free field does not start until 20 to 50 ft from the equipment in most installations.

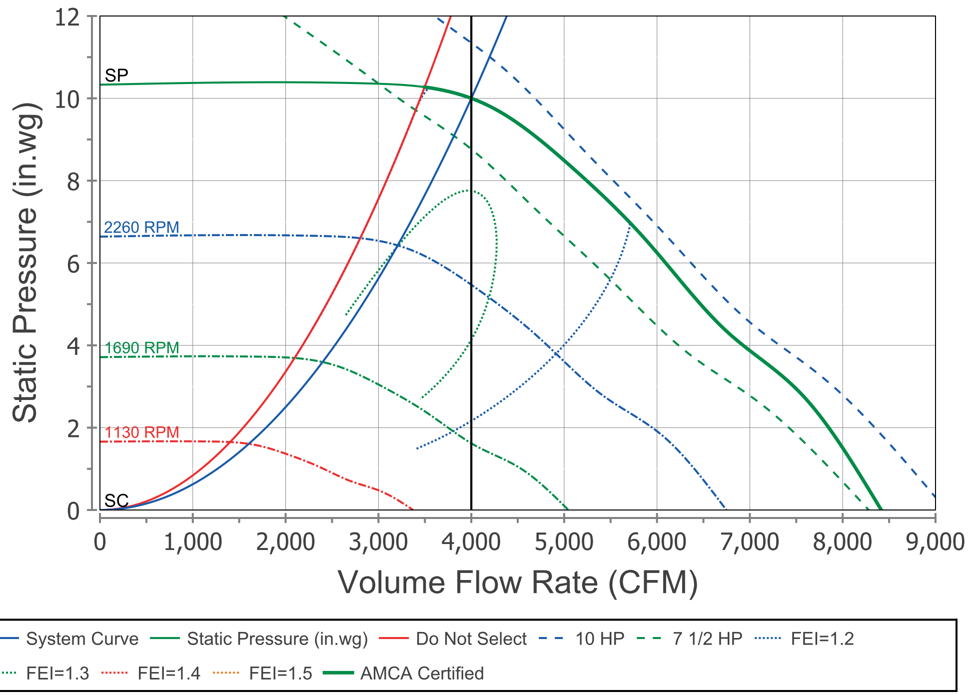
Contact Hartzell Air Movement for more information concerning dBA values.

Quality • Value • Commitment

Hartzell Since 1875
AIR MOVEMENT

Hartzell-FLOW™ v1.0.18 / February 2019

A41-0-182FA100FGFCN3



Fan Tag#:

Vol Flow Rate	4000
Pressure	10
Density (lbs/ft³)	0.075
Oper. Temp. (°F)	70
Fan RPM	2819
Max Safe RPM	2994
Operating Power	8.658
Standard Power	8.658
Static Efficiency	0.727
Outlet Velocity (fpm)	2128
Fan Energy Index (FEI)	1.25
Fan Efficiency Grade (FEG)	FEG80

Discharge Sound Power Levels referred to 10^-12 watts

1	2	3	4	5	6	7	8
107	106	100	100	95	89	81	77

Radiated Sound Power Levels referred to 10^-12 watts

1	2	3	4	5	6	7	8
103	99	90	89	83	76	68	64

Radiated Sound is not AMCA Licensed

Hartzell Air Movement certifies that the model shown is licensed to bear the AMCA Seal.
The ratings shown are based on tests and procedures performed in accordance with AMCA publication 211 and AMCA publication 311 and comply with the requirements of the AMCA Certified Ratings Program.
FEI values are calculated in accordance with ANSI/AMCA Standard 208 and are based on four-pole TEFC motors of the size shown.
Power rating BHP excludes transmission losses.
Performance certified is for Installation Type D: Ducted Inlet, Ducted Outlet.
AMCA Licensed for Sound and Air Performance.
Performance ratings do not include the effects of appurtenances (Accessories).
Sound ratings are based on sound level data obtained in accordance with AMCA Standard 300. The sound power level ratings shown are in decibels, referred to 10^-12 watts, calculated per AMCA Standard 301. Fan Outlet Sound Testing. Values shown are for outlet Lwo sound power levels for:
Installation Type D: Ducted Inlet, Ducted Outlet.
Ratings include the effects of duct end correction.

Discharge Sound Pressure = 89 dBA @ 5ft

Radiated Sound Pressure = 79 dBA @ 5ft

Discharge Sound Power = 101 LwA

Radiated Sound Power = 90 LwA

The A-weighted sound pressure level (dBA) is based on Hartzell Laboratory sound power tests, and is calculated in accordance with AMCA standard 303.

The FEG, dBA, LwA and radiated values are not AMCA International Licensed.

The calculation assumes a free field condition with a directivity factor for hemi-spherical radiation (Q=2).

The installed sound pressure levels are influenced by the installation and acoustic environment, and cannot be guaranteed. Use of this estimate level along for field acceptability test is not recommended.

Although the calculation can be done for any stated distance, the free field does not start until 20 to 50 ft from the equipment in most installations.

Contact Hartzell Air Movement for more information concerning dBA values.

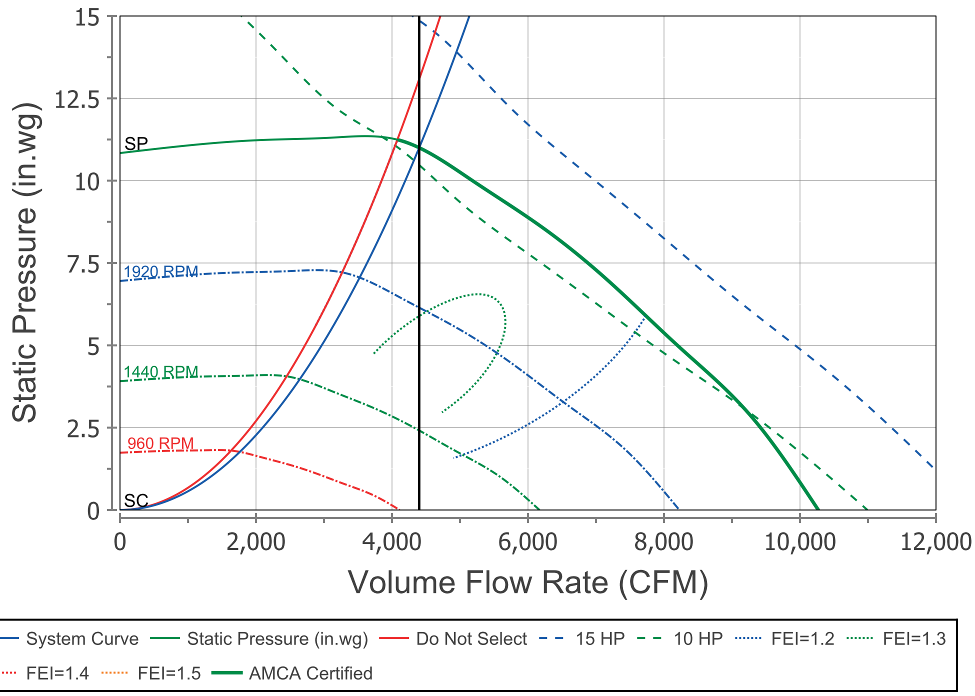
Quality • Value • Commitment

Fan Tag#:

Vol Flow Rate	4400
Pressure	11
Density (lbs/ft³)	0.075
Oper. Temp. (°F)	70
Fan RPM	2397
Max Safe RPM	2448
Operating Power	10.548
Standard Power	10.548
Static Efficiency	0.722
Outlet Velocity (fpm)	1774
Fan Energy Index (FEI)	1.23
Fan Efficiency Grade (FEG)	FEG80

Hartzell-FLOW™ v1.0.18 / February 2019

A41-0-222FA-66FGFCO3



Discharge Sound Power Levels referred to 10^-12 watts

1	2	3	4	5	6	7	8
98	100	98	94	94	87	83	79

Radiated Sound Power Levels referred to 10^-12 watts

1	2	3	4	5	6	7	8
94	93	88	83	82	74	70	66

Radiated Sound is not AMCA Licensed

Hartzell Air Movement certifies that the model shown is licensed to bear the AMCA Seal.
The ratings shown are based on tests and procedures performed in accordance with AMCA publication 211 and AMCA publication 311 and comply with the requirements of the AMCA Certified Ratings Program.
FEI values are calculated in accordance with ANSI/AMCA Standard 208 and are based on four-pole TEFC motors of the size shown.
Power rating BHP excludes transmission losses.
Performance certified is for Installation Type D: Ducted Inlet, Ducted Outlet.
AMCA Licensed for Sound and Air Performance.
Performance ratings do not include the effects of appurtenances (Accessories).
Sound ratings are based on sound level data obtained in accordance with AMCA Standard 300. The sound power level ratings shown are in decibels, referred to 10^-12 watts, calculated per AMCA Standard 301. Fan Outlet Sound Testing. Values shown are for outlet Lwo sound power levels for:
Installation Type D: Ducted Inlet, Ducted Outlet.
Ratings include the effects of duct end correction.

Discharge Sound Pressure = 86 dBA @ 5ft

Radiated Sound Pressure = 75 dBA @ 5ft

Discharge Sound Power = 98 LwA

Radiated Sound Power = 87 LwA

The A-weighted sound pressure level (dBA) is based on Hartzell Laboratory sound power tests, and is calculated in accordance with AMCA standard 303.

The FEG, dBA, LwA and radiated values are not AMCA International Licensed.

The calculation assumes a free field condition with a directivity factor for hemi-spherical radiation (Q=2).

The installed sound pressure levels are influenced by the installation and acoustic environment, and cannot be guaranteed. Use of this estimate level along for field acceptability test is not recommended.

Although the calculation can be done for any stated distance, the free field does not start until 20 to 50 ft from the equipment in most installations.

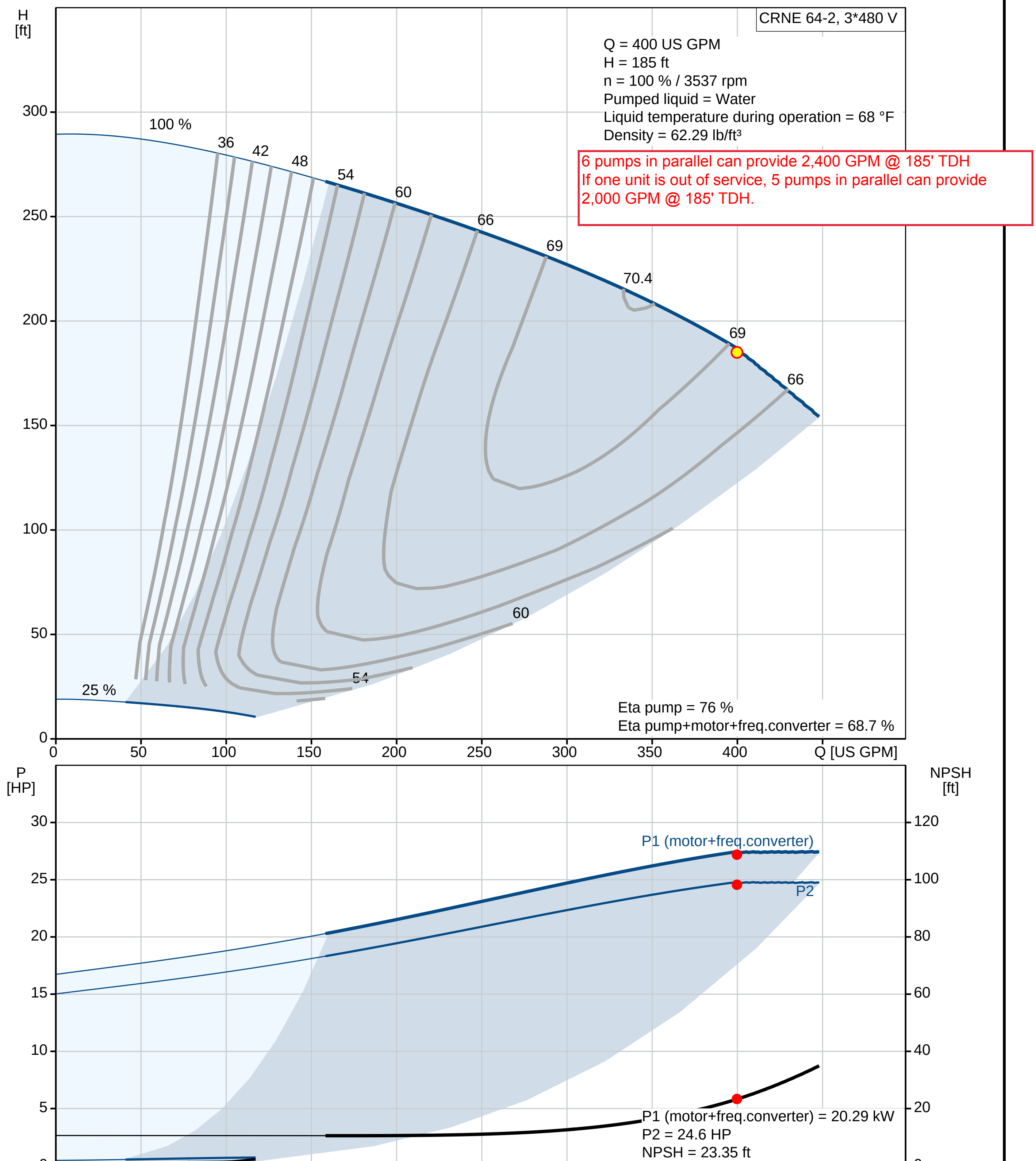
Contact Hartzell Air Movement for more information concerning dBA values.

Proposed Plant Water Pumps

Company name:
Created by:
Phone:

Date: 23/08/2020

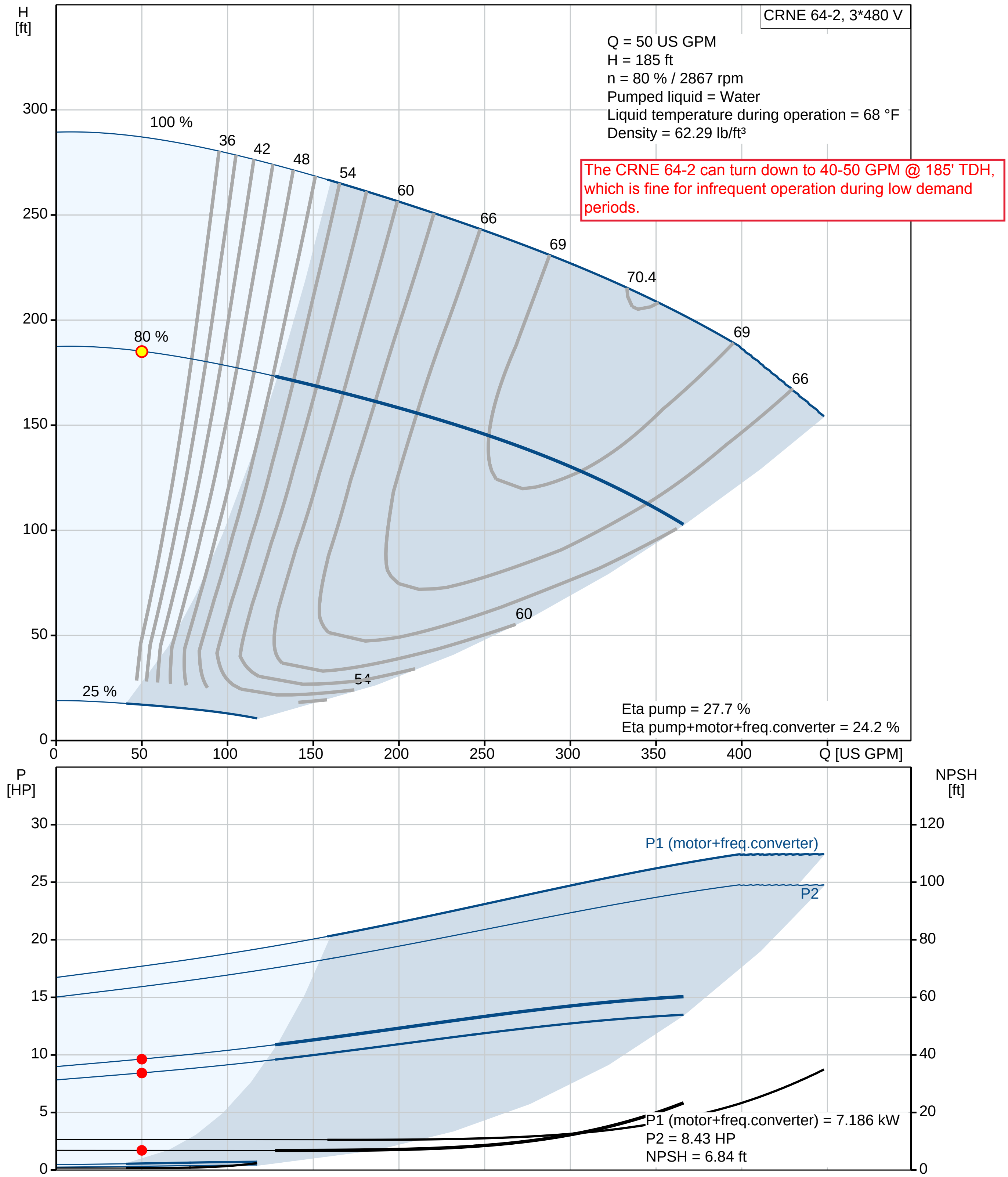
98183946 CRNE 64-2 A-G-A-E-HQQE 60 Hz



Company name:
Created by:
Phone:

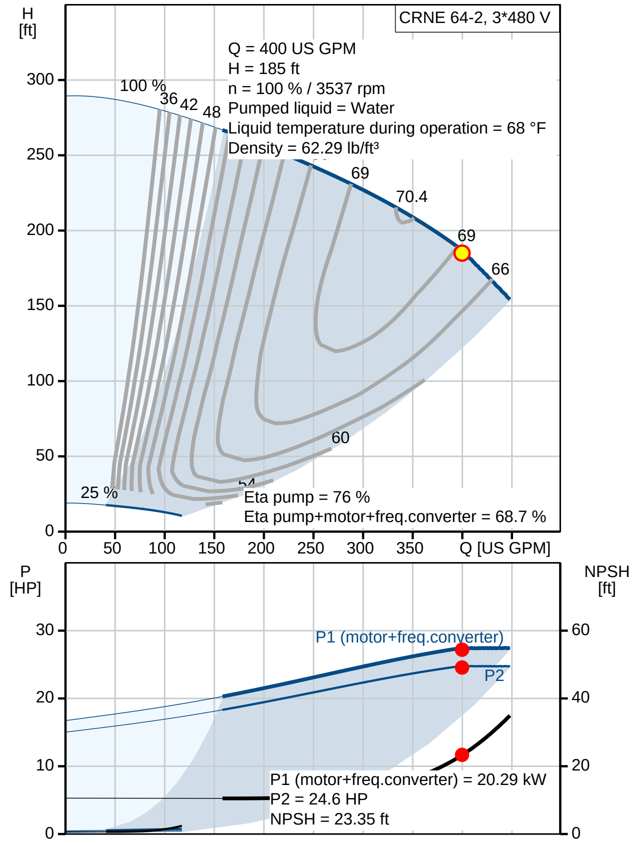
Date: 23/08/2020

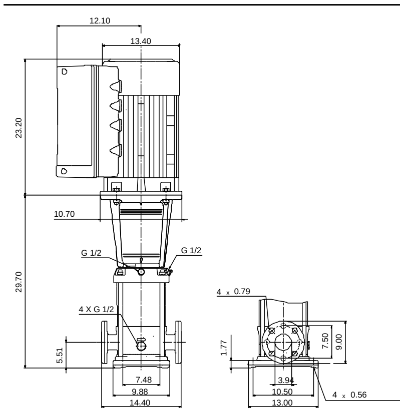
98183946 CRNE 64-2 A-G-A-E-HQQE 60 Hz

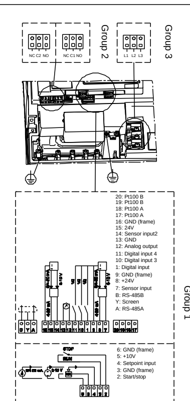


Company name:	
Created by:	
Phone:	
Date:	23/08/2020

Description	Value
General information:	
Product name:	CRNE 64-2 A-G-A-E-HQQE
Product No:	98183946
EAN number:	5711491095165
	5711491095165
Technical:	
Pump speed on which pump data are based:	3521 rpm
Actual calculated flow:	400 US GPM
Resulting head of the pump:	185 ft
Maximum head:	290.4 ft
Actual impeller diameter:	5.63 in
Stages:	2
Impellers:	2
Number of reduced-diameter impellers:	0
Low NPSH:	N
Pump orientation:	Vertical
Shaft seal arrangement:	Single
Code for shaft seal:	HQQE
Approvals on nameplate:	CURUS,NSF61
Curve tolerance:	ISO9906:2012 3B
Pump version:	A
Model:	B
Materials:	
Base:	Stainless steel
	EN 1.4408
	AISI 316
Impeller:	Stainless steel
	EN 1.4401
	AISI 316
Material code:	A
Code for rubber:	E
Bearing:	SIC
Support bearing:	Graflon
Installation:	
Maximum ambient temperature:	104 °F
Maximum operating pressure:	232.06 psi
Max pressure at stated temp:	232 psi / 250 °F
	232 psi / -40 °F
Type of connection:	ANSI
Size of inlet connection:	4 inch
Size of outlet connection:	4 inch
Pressure rating for connection:	PN 16
Flange rating inlet:	150 lb
Flange size for motor:	284TC
Connect code:	G
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-40 .. 248 °F
Selected liquid temperature:	68 °F
Density:	62.29 lb/ft³
Electrical data:	
Motor standard:	NEMA







Company name:
Created by:
Phone:

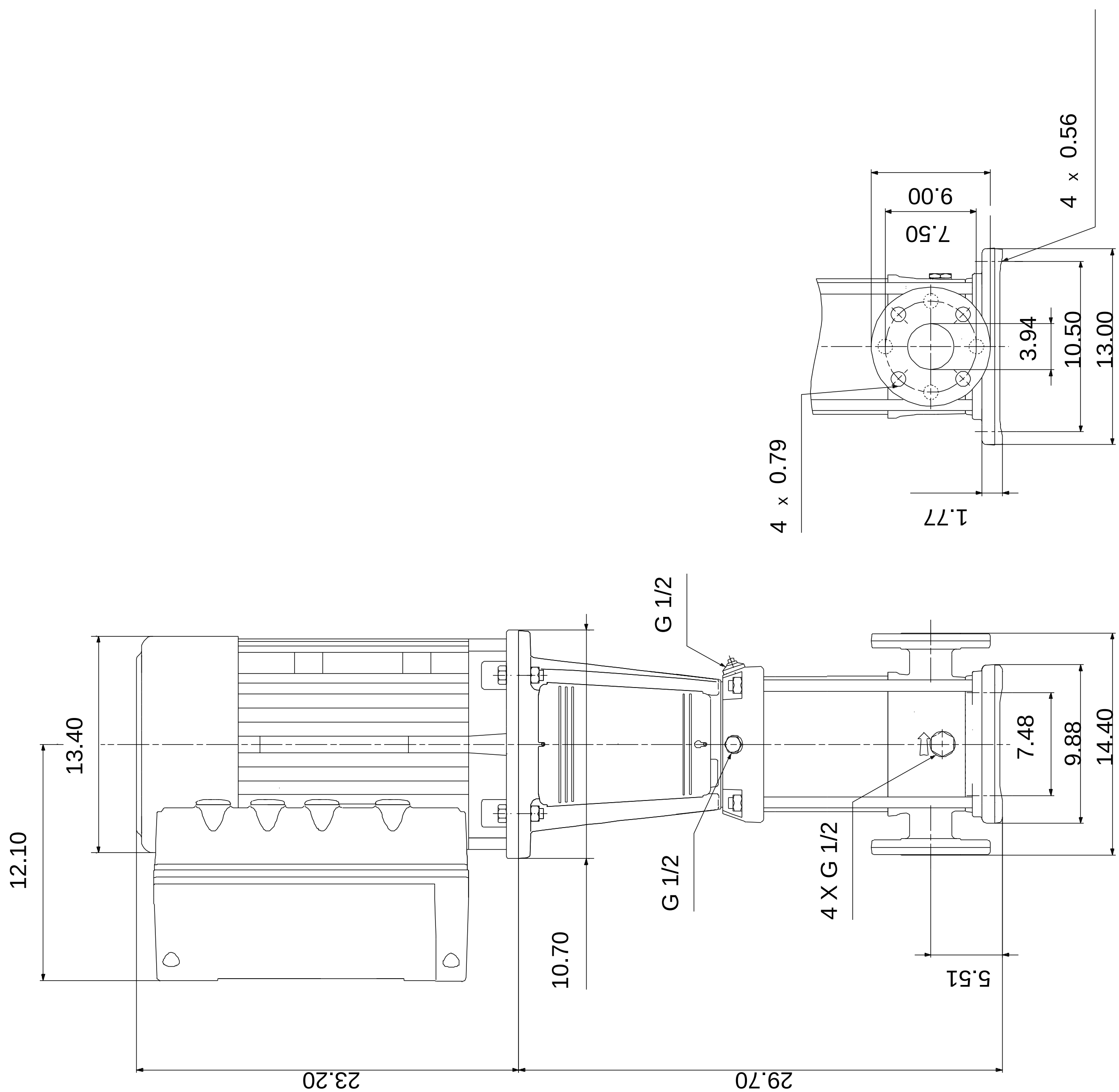
Date: 23/08/2020

Description	Value
Motor type:	160AC
IE Efficiency class:	NEMA Premium / IE3 60Hz
Rated power - P2:	25 HP
Power (P2) required by pump:	25 HP
Mains frequency:	60 Hz
Rated voltage:	3 x 460 V
Service factor:	1.15
Rated current:	30.5 A
Cos phi - power factor:	0.88
Rated speed:	480-3540 rpm
Efficiency:	IE3 91,7%
Motor efficiency at full load:	91.7 %
Number of poles:	2
Enclosure class (IEC 34-5):	IP55
Insulation class (IEC 85):	F
Motor protec:	YES
Motor No:	85901138
Controls:	
Function Module:	ADVANCED I/O
Frequency converter:	Built-in
Pressure sensor:	N
Others:	
DOE Pump Energy Index VL:	0.46
Net weight:	475 lb
Gross weight:	493 lb
Shipping volume:	29 ft^3
Config. file no:	95139704
Country of origin:	US
Custom tariff no.:	8413.70.2040

Company name:
Created by:
Phone:

Date: 23/08/2020

98183946 CRNE 64-2 A-G-A-E-HQQE 60 Hz



Note! All units are in [in] unless others are stated.
Disclaimer: This simplified dimensional drawing does not show all details.

APPENDIX C

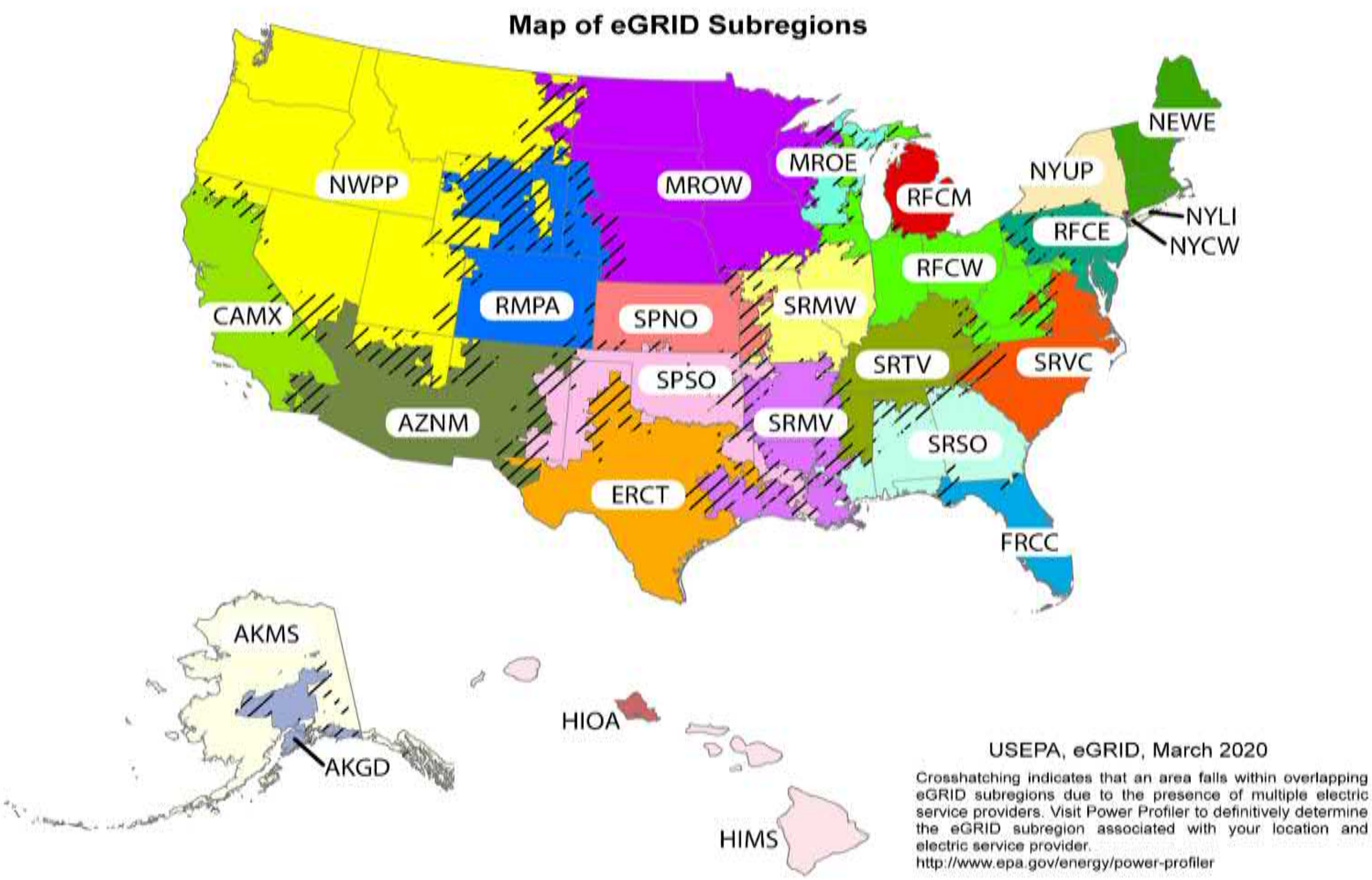
Greenhouse Gas Conversion Tables: eGRID 2018

eGRID Summary Tables 2018

Introduction

This document provides eGRID2018 data summary tables. The tables include subregion and state-level emission rates and resource mix as well as grid gross loss values. Please note that the tables presented here only show a subset of the eGRID2018 data. The entire dataset is in the eGRID2018 Excel file available on the eGRID website.

Table of Contents



Feedback

Customer Satisfaction Survey

Contact EPA

Created: 3/9/2020

1. Subregion Output Emission Rates (eGRID2018)

eGRID subregion acronym	eGRID subregion name	Total output emission rates lb/MWh							Non-baseload output emission rates lb/MWh							Grid Gross Loss (%)
		CO_2	CH_4	N_2O	CO_2e	Annual NO_x	Ozone Season NO_x	SO_2	CO_2	CH_4	N_2O	CO_2e	Annual NO_x	Ozone Season NO_x	SO_2	
AKGD	ASCC Alaska Grid	1,039.6	0.082	0.011	1,045.0	5.5	5.4	1.1	1,262.5	0.110	0.015	1,269.6	6.5	6.4	1.1	5.12%
AKMS	ASCC Miscellaneous	525.1	0.024	0.004	527.0	7.7	7.8	0.7	1,528.3	0.068	0.012	1,533.6	22.8	23.0	2.0	5.12%
AZNM	WECC Southwest	1,022.4	0.077	0.011	1,027.5	0.7	0.7	0.3	1,435.3	0.097	0.014	1,441.8	1.0	0.9	0.3	4.80%
CAMX	WECC California	496.5	0.034	0.004	498.7	0.5	0.4	0.0	929.5	0.047	0.006	932.5	0.8	0.7	0.0	4.80%
ERCT	ERCOT All	931.7	0.066	0.009	936.1	0.5	0.6	0.8	1,261.0	0.083	0.012	1,266.5	0.8	0.8	1.1	4.87%
FRCC	FRCC All	931.8	0.066	0.009	936.1	0.4	0.4	0.3	1,123.9	0.068	0.009	1,128.3	0.4	0.4	0.4	4.88%
HIMS	HICC Miscellaneous	1,110.7	0.118	0.018	1,119.1	7.6	7.6	4.0	1,535.7	0.139	0.022	1,545.8	11.8	11.5	5.0	5.14%
HIOA	HICC Oahu	1,669.9	0.180	0.027	1,682.6	3.5	3.8	8.0	1,682.1	0.159	0.025	1,693.6	4.2	4.2	8.4	5.14%
MROE	MRO East	1,678.0	0.169	0.025	1,689.7	0.9	0.9	0.9	1,634.3	0.149	0.022	1,644.5	0.9	1.0	1.0	4.88%
MROW	MRO West	1,239.8	0.138	0.020	1,249.2	1.0	1.0	1.4	1,764.3	0.192	0.027	1,777.0	1.5	1.4	1.8	4.88%
NEWE	NPCC New England	522.3	0.082	0.011	527.6	0.4	0.4	0.1	931.0	0.086	0.011	936.5	0.5	0.4	0.3	4.88%
NWPP	WECC Northwest	639.0	0.064	0.009	643.4	0.6	0.6	0.4	1,575.1	0.148	0.021	1,585.2	1.4	1.4	0.8	4.80%
NYCW	NPCC NYC/Westchester	596.4	0.022	0.003	597.8	0.3	0.2	0.0	1,067.6	0.022	0.002	1,068.9	0.5	0.5	0.1	4.88%
NYLI	NPCC Long Island	1,184.2	0.139	0.018	1,193.1	0.9	0.8	0.2	1,320.3	0.040	0.005	1,322.8	1.0	0.9	0.4	4.88%
NYUP	NPCC Upstate NY	253.1	0.018	0.002	253.9	0.1	0.1	0.1	931.5	0.043	0.005	934.0	0.5	0.5	0.5	4.88%
RFCE	RFC East	716.0	0.061	0.008	720.0	0.3	0.3	0.5	1,242.6	0.091	0.013	1,248.6	0.7	0.6	0.8	4.88%
RFCM	RFC Michigan	1,312.6	0.129	0.018	1,321.2	0.8	0.8	1.3	1,748.9	0.171	0.024	1,760.3	1.2	1.2	2.1	4.88%
RFCW	RFC West	1,166.1	0.117	0.017	1,174.0	0.8	0.7	0.9	1,828.3	0.179	0.026	1,840.5	1.4	1.1	1.4	4.88%
RMPA	WECC Rockies	1,273.6	0.123	0.018	1,281.9	0.7	0.7	0.4	1,542.6	0.120	0.017	1,550.7	0.8	0.8	0.4	4.80%
SPNO	SPP North	1,163.2	0.124	0.018	1,171.6	0.6	0.7	0.3	1,945.5	0.201	0.029	1,959.2	1.2	1.3	0.7	4.88%
SPSO	SPP South	1,166.6	0.091	0.013	1,172.8	0.8	0.9	1.2	1,603.5	0.118	0.017	1,611.5	1.3	1.3	1.9	4.88%
SRMV	SERC Mississippi Valley	854.6	0.055	0.008	858.4	0.6	0.7	1.0	1,137.6	0.069	0.010	1,142.2	0.9	0.9	1.4	4.88%
SRMW	SERC Midwest	1,664.2	0.185	0.027	1,676.8	1.1	0.8	2.5	1,907.0	0.204	0.030	1,920.9	1.1	0.9	2.7	4.88%
SRSO	SERC South	1,027.9	0.081	0.012	1,033.5	0.5	0.4	0.3	1,413.7	0.107	0.015	1,420.9	0.8	0.7	0.5	4.88%
SRTV	SERC Tennessee Valley	1,031.5	0.097	0.014	1,038.1	0.6	0.5	0.6	1,644.3	0.149	0.021	1,654.4	0.8	0.8	0.9	4.88%
SRVC	SERC Virginia/Carolina	743.3	0.067	0.009	747.5	0.4	0.4	0.3	1,422.6	0.128	0.018	1,430.9	0.9	0.8	0.5	4.88%
U.S.		**947.2**	**0.085**	**0.012**	**952.9**	**0.6**	**0.6**	**0.7**	**1,432.3**	**0.117**	**0.017**	**1,440.1**	**1.0**	**0.9**	**1.0**	**4.87%**

Created: 3/9/2020

2. Subregion Resource Mix (eGRID2018)

eGRID subregion acronym	eGRID subregion name	Nameplate Capacity (MW)	Net Generation (MWh)	Generation Resource Mix (percent)*										
				Coal	Oil	Gas	Other Fossil	Nuclear	Hydro	Biomass	Wind	Solar	Geo-thermal	Other unknown/ purchased fuel
AKGD	ASCC Alaska Grid	2,417	4,641,060	13.5%	8.3%	61.0%	0.0%	0.0%	13.6%	0.9%	2.6%	0.0%	0.0%	0.0%
AKMS	ASCC Miscellaneous	1,054	1,603,241	0.0%	26.3%	7.2%	0.0%	0.0%	64.4%	0.2%	2.1%	0.0%	0.0%	0.0%
AZNM	WECC Southwest	64,435	165,353,383	26.7%	0.0%	41.1%	0.0%	18.8%	3.4%	0.4%	1.8%	4.4%	3.4%	0.0%
CAMX	WECC California	111,738	200,103,502	4.4%	0.0%	45.2%	0.7%	9.1%	11.0%	2.8%	7.3%	14.9%	4.2%	0.3%
ERCT	ERCOT All	168,673	411,784,692	22.6%	0.0%	48.5%	0.4%	10.0%	0.2%	0.2%	17.0%	0.8%	0.0%	0.1%
FRCC	FRCC All	102,499	233,469,406	11.6%	0.9%	70.6%	0.0%	12.6%	0.1%	2.6%	0.0%	0.9%	0.0%	0.6%
HIMS	HICC Miscellaneous	1,265	2,743,591	0.0%	66.2%	0.0%	0.0%	0.0%	3.5%	1.9%	14.6%	2.9%	4.0%	6.9%
HIOA	HICC Oahu	2,354	7,053,182	18.6%	69.9%	0.0%	0.8%	0.0%	0.0%	6.4%	2.8%	1.5%	0.0%	0.0%
MROE	MRO East	11,489	24,091,646	64.1%	0.5%	22.6%	0.1%	0.0%	5.3%	4.3%	3.1%	0.0%	0.0%	0.1%
MROW	MRO West	81,925	236,704,124	51.8%	0.1%	8.0%	0.0%	10.6%	6.0%	1.1%	21.7%	0.5%	0.0%	0.2%
NEWE	NPCC New England	45,440	105,482,006	1.0%	1.2%	48.9%	0.2%	29.8%	6.7%	7.7%	3.4%	1.1%	0.0%	0.1%
NWPP	WECC Northwest	92,607	294,782,039	21.3%	0.2%	15.7%	0.3%	3.3%	47.7%	1.2%	8.3%	1.3%	0.6%	0.1%
NYCW	NPCC NYC/Westchester	17,331	43,455,637	0.0%	1.4%	60.1%	0.0%	37.6%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%
NYLI	NPCC Long Island	6,322	10,573,426	0.0%	5.5%	84.3%	0.0%	0.0%	0.0%	9.0%	0.0%	1.3%	0.0%	0.0%
NYUP	NPCC Upstate NY	30,838	84,997,204	0.8%	0.6%	25.9%	0.0%	31.3%	34.6%	2.0%	4.7%	0.2%	0.0%	0.0%
RFCE	RFC East	98,984	297,325,701	15.5%	0.5%	39.6%	0.2%	38.9%	2.0%	1.7%	1.0%	0.5%	0.0%	0.0%
RFCM	RFC Michigan	34,643	94,438,353	43.1%	1.3%	32.5%	1.8%	13.6%	0.0%	2.0%	5.7%	0.1%	0.0%	0.0%
RFCW	RFC West	192,653	532,056,236	44.4%	0.3%	21.0%	0.7%	28.3%	0.9%	0.6%	3.6%	0.1%	0.0%	0.0%
RMPA	WECC Rockies	23,700	65,413,620	44.8%	0.0%	25.5%	0.0%	0.0%	12.5%	0.3%	15.3%	1.6%	0.0%	0.1%
SPNO	SPP North	30,309	70,807,115	46.9%	0.2%	11.7%	0.0%	12.9%	0.2%	0.1%	27.9%	0.1%	0.0%	0.0%
SPSO	SPP South	62,596	160,677,686	30.9%	1.7%	40.0%	0.3%	0.0%	2.8%	1.4%	22.4%	0.4%	0.0%	0.1%
SRMV	SERC Mississippi Valley	58,996	177,877,883	16.8%	1.0%	56.5%	1.7%	20.7%	1.3%	1.6%	0.0%	0.1%	0.0%	0.3%
SRMW	SERC Midwest	40,774	128,388,555	70.2%	0.1%	9.4%	0.0%	14.8%	1.0%	0.1%	4.2%	0.0%	0.0%	0.2%
SRSO	SERC South	88,734	262,135,271	26.3%	0.2%	47.3%	0.0%	18.5%	3.0%	3.6%	0.0%	1.0%	0.0%	0.0%
SRTV	SERC Tennessee Valley	72,620	224,259,819	35.5%	0.1%	26.5%	0.0%	27.5%	9.5%	0.8%	0.0%	0.2%	0.0%	0.0%
SRVC	SERC Virginia/Carolina	117,248	328,151,742	19.1%	0.6%	34.6%	0.1%	37.8%	2.3%	2.8%	0.4%	2.2%	0.0%	0.1%
U.S.		**1,561,643**	**4,168,370,118**	**27.5%**	**0.6%**	**35.1%**	**0.3%**	**19.4%**	**6.9%**	**1.6%**	**6.5%**	**1.5%**	**0.4%**	**0.1%**

*percentages may not sum to 100 due to rounding

Created: 3/9/2020

3. State Output Emission Rates (eGRID2018)

State	Total output emission rates (lb/MWh)						
	CO_2	CH_4	N_2O	CO_2e	Annual NO_x	Ozone Season NO_x	SO_2
AK	907.5	0.067	0.009	912.0	6.0	6.1	1.0
AL	864.0	0.063	0.009	868.3	0.4	0.4	0.2
AR	1,211.3	0.114	0.017	1,219.1	0.7	0.7	1.6
AZ	967.0	0.077	0.011	972.2	0.6	0.6	0.3
CA	420.4	0.027	0.003	422.0	0.4	0.3	0.0
CO	1,362.6	0.130	0.019	1,371.4	0.7	0.7	0.4
CT	506.4	0.050	0.006	509.5	0.3	0.3	0.1
DC	438.9	0.022	0.002	440.1	4.2	4.6	0.1
DE	898.3	0.034	0.004	900.4	0.4	0.4	0.2
FL	943.3	0.068	0.009	947.7	0.4	0.4	0.3
GA	926.4	0.079	0.012	931.9	0.4	0.3	0.3
HI	1,513.3	0.162	0.025	1,524.8	4.7	4.8	6.9
IA	1,069.9	0.109	0.016	1,077.4	0.8	0.8	1.1
ID	160.2	0.007	0.001	160.7	0.2	0.2	0.1
IL	812.9	0.083	0.012	818.5	0.4	0.4	0.9
IN	1,736.5	0.176	0.025	1,748.5	1.6	1.1	1.2
KS	989.3	0.107	0.016	996.6	0.7	0.8	0.2
KY	1,822.2	0.198	0.029	1,835.7	1.2	1.1	1.4
LA	836.0	0.049	0.007	839.4	0.7	0.8	1.0
MA	727.6	0.099	0.013	733.8	0.6	0.5	0.2
MD	835.7	0.081	0.011	841.2	0.4	0.3	0.5
ME	257.7	0.154	0.022	268.2	0.6	0.6	0.3
MI	1,108.3	0.111	0.016	1,115.8	0.7	0.7	1.2
MN	995.4	0.117	0.017	1,003.1	0.7	0.7	0.6
MO	1,699.6	0.195	0.028	1,712.9	1.3	0.8	2.5
MS	917.0	0.039	0.005	919.5	0.4	0.5	0.2
MT	1,157.1	0.129	0.019	1,165.9	1.2	1.1	0.9
NC	799.6	0.070	0.010	804.1	0.5	0.6	0.3
ND	1,505.2	0.170	0.025	1,516.9	1.5	1.6	1.8
NE	1,406.4	0.164	0.024	1,417.5	1.2	1.3	3.2
NH	299.5	0.099	0.013	305.8	0.3	0.2	0.2
NJ	500.1	0.033	0.004	502.1	0.2	0.2	0.0
NM	1,333.2	0.108	0.015	1,340.4	1.1	1.1	0.2
NV	744.8	0.029	0.004	746.6	0.5	0.6	0.2
NY	417.1	0.029	0.004	418.7	0.2	0.2	0.1
OH	1,321.5	0.123	0.018	1,329.8	0.8	0.7	1.4
OK	889.7	0.056	0.008	893.4	0.6	0.6	0.7
OR	313.0	0.018	0.002	314.2	0.3	0.3	0.1
PA	784.3	0.068	0.010	788.8	0.4	0.3	0.7
RI	867.9	0.016	0.002	868.8	0.4	0.4	0.0
SC	630.5	0.059	0.009	634.6	0.3	0.3	0.2
SD	516.8	0.047	0.007	520.0	0.2	0.3	0.2
TN	743.6	0.070	0.010	748.4	0.4	0.3	0.4
TX	979.1	0.069	0.010	983.7	0.6	0.6	0.9
UT	1,598.0	0.167	0.024	1,609.4	1.6	1.6	0.7
VA	739.3	0.064	0.009	742.8	0.5	0.4	0.2
VT	45.1	0.193	0.025	57.5	0.2	0.2	0.0
WA	198.6	0.021	0.003	200.0	0.2	0.2	0.0
WI	1,386.9	0.138	0.020	1,396.3	0.6	0.6	0.4
WV	1,945.9	0.228	0.033	1,961.5	1.2	1.1	1.5
WY	2,048.4	0.225	0.033	2,063.8	1.6	1.6	1.4
U.S.	**947.2**	**0.085**	**0.012**	**952.9**	**0.6**	**0.6**	**0.7**

Created: 3/9/2020

4. State Resource Mix (eGRID2018)														
State	Nameplate Capacity (MW)	Net Generation (MWh)	Generation Resource Mix (percent)*											
			Coal	Oil	Gas	Other Fossil	Nuclear	Hydro	Biomass	Wind	Solar	Geo-thermal	Other unknown/ purchased fuel
AK	3,471	6,244,300	10.1%	12.9%	47.2%	0.0%	0.0%	26.6%	0.7%	2.5%	0.0%	0.0%	0.0%
AL	38,716	143,221,259	21.8%	0.0%	40.1%	0.0%	27.6%	7.8%	2.4%	0.0%	0.2%	0.0%	0.0%
AR	19,659	67,999,352	44.1%	0.1%	30.3%	0.0%	18.7%	4.5%	2.0%	0.0%	0.3%	0.0%	0.0%
AZ	40,198	111,639,090	27.5%	0.0%	33.0%	0.0%	27.9%	6.3%	0.2%	0.5%	4.6%	0.0%	0.0%
CA	107,912	195,212,860	0.1%	0.0%	45.9%	0.7%	9.3%	13.4%	3.1%	7.2%	13.8%	6.0%	0.3%
CO	20,535	55,375,731	47.6%	0.0%	29.6%	0.0%	0.0%	2.8%	0.3%	17.6%	1.9%	0.0%	0.1%
CT	12,773	39,453,553	0.8%	0.9%	50.7%	0.0%	42.8%	1.4%	3.1%	0.0%	0.3%	0.0%	0.0%
DC	43	74,889	0.0%	0.0%	24.5%	0.0%	0.0%	0.0%	75.5%	0.0%	0.0%	0.0%	0.0%
DE	4,015	6,240,644	4.4%	3.2%	86.5%	4.0%	0.0%	0.0%	0.9%	0.1%	0.8%	0.0%	0.0%
FL	105,450	243,456,187	12.4%	0.9%	70.3%	0.0%	12.0%	0.1%	2.7%	0.0%	1.0%	0.0%	0.6%
GA	52,507	129,232,893	24.9%	0.3%	40.2%	0.1%	26.6%	2.5%	3.9%	0.0%	1.5%	0.0%	0.0%
HI	3,619	9,796,773	13.4%	68.9%	0.0%	0.6%	0.0%	1.0%	5.1%	6.1%	1.9%	1.1%	1.9%
IA	25,146	63,191,960	45.2%	0.2%	11.4%	0.0%	7.7%	1.5%	0.3%	33.7%	0.0%	0.0%	0.0%
ID	6,316	18,172,119	0.1%	0.0%	18.0%	0.0%	0.0%	60.7%	2.7%	14.6%	3.1%	0.5%	0.4%
IL	65,540	187,990,218	31.7%	0.0%	9.2%	0.1%	52.2%	0.1%	0.2%	6.3%	0.0%	0.0%	0.1%
IN	42,779	113,451,150	68.3%	0.1%	23.6%	2.0%	0.0%	0.2%	0.4%	4.8%	0.3%	0.0%	0.3%
KS	21,546	51,683,745	39.6%	0.1%	5.8%	0.0%	17.7%	0.1%	0.1%	36.6%	0.0%	0.0%	0.0%
KY	30,427	78,804,497	75.1%	0.1%	18.5%	0.1%	0.0%	5.6%	0.5%	0.0%	0.1%	0.0%	0.0%
LA	36,634	101,862,424	11.6%	4.3%	60.3%	2.6%	16.8%	1.2%	2.6%	0.0%	0.0%	0.0%	0.6%
MA	18,841	27,123,443	0.0%	1.7%	67.8%	0.0%	16.4%	2.4%	7.4%	0.8%	3.5%	0.0%	0.0%
MD	18,369	43,783,523	23.0%	0.6%	31.6%	0.0%	34.2%	6.5%	1.9%	1.3%	0.9%	0.0%	0.0%
ME	5,659	11,280,700	0.6%	1.7%	20.7%	1.4%	0.0%	28.9%	24.5%	21.1%	0.1%	0.0%	0.9%
MI	39,850	115,834,924	36.5%	1.0%	26.8%	1.5%	26.3%	0.8%	2.3%	4.7%	0.1%	0.0%	0.0%
MN	23,325	61,425,572	38.2%	0.1%	13.8%	0.0%	23.8%	1.7%	3.2%	17.4%	1.7%	0.0%	0.2%
MO	25,772	81,304,230	73.4%	0.1%	8.5%	0.0%	13.1%	1.1%	0.2%	3.5%	0.1%	0.0%	0.0%
MS	19,338	63,473,771	8.3%	0.0%	78.0%	0.0%	10.9%	0.0%	2.3%	0.0%	0.5%	0.0%	0.0%
MT	7,743	28,195,174	47.4%	1.6%	1.7%	0.0%	0.0%	40.4%	0.1%	7.6%	0.1%	0.0%	1.1%
NC	49,083	134,162,507	23.6%	0.5%	32.4%	0.2%	31.4%	4.9%	1.9%	0.4%	4.5%	0.0%	0.2%
ND	10,230	42,612,542	64.6%	0.1%	2.4%	0.1%	0.0%	7.5%	0.0%	25.2%	0.0%	0.0%	0.1%
NE	11,072	36,966,216	63.0%	0.0%	2.6%	0.0%	15.2%	3.7%	0.3%	15.0%	0.1%	0.0%	0.0%
NH	4,740	17,063,035	3.7%	1.0%	17.5%	0.0%	59.0%	7.9%	8.4%	2.4%	0.0%	0.0%	0.0%
NJ	28,415	74,975,549	1.6%	0.5%	51.8%	0.3%	42.6%	0.0%	1.9%	0.0%	1.2%	0.0%	0.0%
NM	13,237	32,534,843	41.2%	0.1%	35.3%	0.0%	0.0%	0.5%	0.1%	18.7%	4.1%	0.0%	0.0%
NV	21,064	39,607,668	6.3%	0.0%	67.4%	0.0%	0.0%	4.7%	0.1%	0.8%	11.8%	8.7%	0.1%
NY	51,892	132,500,582	0.5%	1.2%	38.3%	0.0%	32.4%	22.0%	2.3%	3.0%	0.2%	0.0%	0.0%
OH	48,923	126,184,611	46.5%	1.0%	35.0%	0.6%	14.5%	0.2%	0.6%	1.4%	0.1%	0.0%	0.0%
OK	35,663	86,223,721	17.3%	0.0%	48.3%	0.1%	0.0%	2.2%	0.4%	31.7%	0.1%	0.0%	0.0%
OR	19,174	63,917,832	2.0%	0.0%	28.0%	0.0%	0.0%	55.5%	1.7%	11.7%	0.9%	0.3%	0.0%
PA	69,518	215,390,666	20.5%	0.3%	35.5%	0.3%	38.8%	1.7%	1.4%	1.7%	0.0%	0.0%	0.0%
RI	2,547	8,372,772	0.0%	0.9%	94.3%	0.0%	0.0%	0.0%	2.5%	1.9%	0.3%	0.0%	0.0%
SC	33,321	99,322,723	19.6%	0.3%	21.8%	0.0%	53.1%	2.3%	2.3%	0.0%	0.5%	0.0%	0.0%
SD	5,804	12,616,396	18.5%	0.1%	9.3%	0.0%	0.0%	49.7%	0.0%	22.5%	0.0%	0.0%	0.0%
TN	28,022	81,539,018	25.7%	0.1%	16.4%	0.0%	44.4%	11.9%	1.2%	0.1%	0.2%	0.0%	0.0%
TX	191,885	476,834,936	23.4%	0.0%	50.2%	0.5%	8.6%	0.2%	0.3%	15.9%	0.7%	0.0%	0.1%
UT	11,495	39,375,424	65.8%	0.1%	22.2%	0.0%	0.0%	2.4%	0.2%	2.0%	5.6%	1.1%	0.6%
VA	35,922	94,558,960	9.3%	1.0%	52.6%	0.0%	30.9%	0.5%	4.9%	0.0%	0.8%	0.0%	0.0%
VT	866	2,175,006	0.0%	0.1%	0.1%	0.0%	0.0%	58.3%	19.6%	17.2%	4.7%	0.0%	0.0%
WA	34,271	116,746,864	4.6%	0.0%	9.0%	0.4%	8.3%	69.3%	1.6%	6.8%	0.0%	0.0%	0.0%
WI	23,499	65,802,102	50.6%	0.2%	25.3%	0.0%	15.4%	3.6%	2.2%	2.5%	0.1%	0.0%	0.0%
WV	20,675	67,249,025	92.2%	0.2%	2.1%	0.0%	0.0%	2.7%	0.0%	2.6%	0.0%	0.0%	0.0%
WY	14,146	46,112,136	86.0%	0.1%	1.9%	0.8%	0.0%	2.1%	0.0%	8.8%	0.0%	0.0%	0.2%
U.S.	**1,561,643**	**4,168,370,118**	**27.5%**	**0.6%**	**35.1%**	**0.3%**	**19.4%**	**6.9%**	**1.6%**	**6.5%**	**1.5%**	**0.4%**	**0.1%**

Created: 3/9/2020

APPENDIX D

Aeration Calculations

Base Case

Converting Airflow Bins from Fine Bubble SOR to AOR

Condition	Airflow Required (cfm)	lbs O_2 per CF	SOR (lb/min)	AOR/SOR Fine Bubble	AOR (lb/min)	AOR (lb/hr)
Average	10,000	0.0173	173	0.33	57.09	3,425
Maximum	14,700	0.0173	254	0.33	83.92	5,035

Notes:

1. Average and maximum airflow conditions based on proposed aeration system conditions provided by design engineer.
2. lbs O2 per CF is based on standard conversion.
3. AOR/SOR for fine bubble systems based on industry standards.

Converting AOR to SOR for Surface Aerators

Constant Values

Alpha =	0.82	
Beta =	0.95	
Theta =	1.024	
Tank Depth =	0.0	ft
Oxygen Transfer Rate =	3.50	(lb O2/hp-hr)
Csat, 20 =	9.09	

Pf	30.5	in-mercury
PMSL	29.92	in-mercury
WW Temperatu	15	Celsuis
Value of theta (:	0.888	

Conditon .	Residual DO (mg/l)	WW Temp. (°C)	DO Sat (sea level)	AOR (lb/hr)	C_{ST}	τ	Ambient Press. (psi)	Standard Press. (psi)	Ω	Depth Correction Factor, c	C_{SC}	$\theta^{(T-20)}$	AOR/SOR	SOR (lb/hr)	Aerator Power BHP	Motor Efficiency %	VFD Efficiency %	Power Draw kW	Energy Usage kWh/Year	Energy Cost $/Year
Average	0.2	15	11.1	3,425	10	1.1	14.98	14.7	1.0	0.25	8.9	0.9	0.77	4,470	1,277	95.0%	97%	1,036	8,621,782	$ 957,018
Max	0.2	15	11.1	5,035	10	1.1	14.98	14.7	1.0	0.25	8.9	0.9	0.77	6,571	1,877	95.0%	97%	1,523	667,054	$ 74,043
Average	0.2	15	11.1	4,230									0.77	5,520	1,577	95.0%	97%	1,279	4,644,418	$515,530
																		Total	9,288,836	$1,031,061

Notes

1. DO = dissolved oxygen; based on residual DO under ammonia trim control
2. WW temp based on typical wastewater temperature
3. DO saturation based on wastewater temperature
4. AOR = actual oxygen requirements calculated using proposed airflow requirements.
5. SOR = Standard oxygen requirements

Using SOR for Surface Aerators to Calculate Power Draw

Condition	AOR lb/hr	AOR/SOR Surface Aerators	SOR lb/hr	Design Transfer Rate (O2/HP-h)	BHP Surface Aerators	Motor Efficiency (%)	VFD Efficiency (%)	Power Draw (kW)	Annual Hours of Operation	Energy Usage (kWh/year)	Annual GHG Emissions (mtCO2e/yr)
Average	3,425	0.77	4,470	3.5	1,277	95.0%	97%	1,036	8,322	8,621,782	2,869.77
Maximum	5,035	0.77	6,571	3.5	1,877	95.0%	97%	1,523	438	667,054	222.03
									Total	**9,288,836**	**3,091.80**

Notes:

1. AOR based on above calculation.
2. AOR/SOR surface aerators based on industry standard calculation presented in Appendix.
3. Oxygen transfer rate based on standard surface aerator transfer rate.
4. Aerators BHP based on site standards, AOR/SOR ratio for surface aerators and aeration calculation.
5. Motor efficiency based on premium efficiency standards for motors over 100 hp.
6. VFD efficiency based on typical thermal losses.
7. Annual operating hours for each condition assumed based on typical wet weather conditions at WWTPs.

Proposed Case, Aeration Blowers & Fine Bubble Diffusion

Aeration Blowers

Condition	Number of Blowers	Flowrate per Blower (cfm)	Pressure (PSI)	Motor Efficiency (%)	Power Draw (kW)	Percent of Time	Annual Hours of Operation	Energy Usage (kWh/year)	Annual GHG Emissions (mtCO2e/yr)
Average	2	5,000	8.5	95.0%	317.3	95%	8,322	2,640,973	879.05

Maximum	3	4,900	8.7	95.0%	476.0	5%	438	208,498	69.40
							Total	**2,849,471**	**948.45**

Notes:

1. Average and maximum airflow conditions and pressure based on proposed aeration system conditions provided by design engineer.
2. Motor efficiency based on typical premium efficiency motors of similar size.
3. Blower power draw information provided by manufacturers representative.
4. Annual operating hours for each condition assumed based on typical wet weather conditions at WWTPs.

Savings

Condition	Annual Energy Usage (kWh)	Annual Energy Cost ($)	Annual GHG Emissions (mtCO2e/yr)
Existing	9,288,836	$1,031,061	3,091.80
Proposed	2,849,471	$316,291	948.45
Total Savings	**6,439,364**	**$714,769**	**2,143.35**

Notes:

1. Cost based on unit cost of $0.111 per kWh.
2. GHG savings based on the MA emissions rate of 733.8 lbs CO2e/MWh from EPAs eGRID 2018 summary table for Massachussets.