Las Virgenes - Triunfo Joint Powers Authority

Tapia WRF – Process Air Evaluation

Technical Memorandum No. 2
Blower Evaluation

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LAS VIRGENES - TRIUNFO JOINT POWERS AUTHORITY

Tapia WRF – Process Air Evaluation

TECHNICAL MEMORANDUM
NO. 2

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1.0 EXECUTIVE SUMMARY

Technical Memorandum No. 1 recommended several improvements to reduce air usage at the Tapia WRF. Most significant is the recommendation to replace the existing spiral-roll diffuser system within the aeration basins with a new full-floor cover system. This improvement is expected to reduce average aeration airflows by an estimated 69 percent. This blower evaluation was conducted to characterize the existing blower system's ability to accommodate the significant reduction in airflow, and small increase in required blower discharge pressures resulting from the proposed aeration basin diffuser replacement. This evaluation also considers alternative technologies to improve energy efficiency and system reliability.

The results of the blower evaluation indicate that the existing 900 hp Roots blowers at the Tapia WRF are not capable of accommodating the required turndown and blower discharge pressures associated with the recommended aeration basin improvements. The existing 250 hp Hoffman blowers will not be able to satisfy peak plant air demands associated with the aeration basin improvements. Our analysis indicates that approximately $60,000 to $70,000 could be saved in annual energy costs by replacing the existing Roots blowers with one of the following technologies:

- New single-stage blowers with dual-point control
- New high-speed direct-drive (Turbo) blowers

The blower evaluation considered the total cost of ownership for each of three selected blower replacement alternatives. Energy costs proved to be the single largest contributor to the overall cost of ownership. Energy costs are directly influenced by wire-to-air efficiency. Wire-to-air efficiency accounts for all energy losses, including those associated with the blower impeller and connected electrical components such as motors, variable frequency drives, and harmonic filters. Wire-to-air efficiency formed the basis for the characterization of energy costs associated with each blower replacement alternative.

Based on the results of the evaluation, we recommend the replacement of two existing Roots blowers with two new 350 hp single-stage blowers at project year 0 (blower replacement Alternative 1). This alternative provides the maximum annual energy savings and the lowest 20-year lifecycle costs of ownership. The improved wire-to-air efficiencies provided by this alternative will significantly reduce annual energy usage compared to the existing Hoffman blowers (used as the baseline for blower performance). The expected simple payback period for this alternative is approximately 19 years.

A summary of blower replacement Alternative 1 is provided in Table 1.1.

Table 1.1 Blower Replacement Summary - Alternative 1

Description	Units	Parameter Values
Blower Technology	N/A	Single-Stage
Manufacturer/Model	N/A	Siemens/KA10
Blower Size	(hp)	350
Wire-to-Air Efficiency(1)	(%)	75 - 78
Yr-0 Capital Costs	($)	1,315,150
Expected Year-0 Energy Cost Savings	($)	69,300
Simple Payback Period	(Yr)	19.0

Notes:
(1) Expected efficiencies are based on a review of data provided by the blower manufacturer. Efficiency depends on operating point of blower.

2.0 BACKGROUND AND INTRODUCTION

Technical Memorandum No. 1 recommended several measures to reduce process air usage at the Tapia WRF. Improvements that are expected to result in significant reductions to process air usage include the following:

1. The replacement of the existing spiral-roll diffuser system within the aeration basins with a new full-floor cover system is expected to reduce average aeration airflows by an estimated 69 percent.

2. The repair of leaks from the aboveground air piping at the Tapia WRF is expected to reduce process air usage by an estimated flow of 500 SCFM.

The blower system operating criteria established in TM-1 are based on these process airflow reductions. These criteria form the basis for the evaluation of the existing blowers and replacement alternatives. Blower system operating criteria are presented in Table 2.1.

The plant “reliability” modes shown in Table 2.1 are discussed in TM-1. They represent the operation of the plant with one or two aeration basins out of service for maintenance.

The objective of this technical memorandum is to characterize the performance of the existing blowers, and recommend a blower replacement alternative that will satisfy the operating conditions presented in Table 2.1 while minimizing costs of ownership. This memorandum also includes an overview of each available blower technology.

Table 2.1 Blower Operating Criteria

Parameter	Unit	Value
System Pressure[1]	(psig)	8.0
Minimum Inlet Air Temperature	(°F)	40
Annual Average Inlet Air Temperature	(°F)	63.5
Maximum Inlet Air Temperature	(°F)	100
Relative Humidity	(%)	58
Barometric Pressure	(psia)	14.5
Yr-0 Minimum Air Demand	(SCFM)	5,350
Yr-0 Average Air Demand	(SCFM)	7,380
Yr-0 Peak Air Demand		
Normal Operation	(SCFM)	12,270
Reliability Mode 1[3]	(SCFM)	13,370
Reliability Mode 2[4]	(SCFM)	18,155
Future (Yr-20) Peak Air Demand[2]		
Normal Operation	(SCFM)	15,750
Reliability Mode 1[3]	(SCFM)	17,340
Reliability Mode 2[4]	(SCFM)	24,100

Notes:
(1) Pressure required at discharge of blowers. Average discharge pressure of 7.8 psig increases to 7.9 psig during operation in “reliability” modes during future peak conditions. Discharge pressure of 8.0 psig was assumed for conservatism.
(2) Future airflows are based on a plant build-out influent flow of 12 MGD.
(3) Peak flows during operation in Reliability Mode No. 1 are based on aeration basin 2 or 5 and basin 1 or 6 out of service.
(4) Peak flows during operation in Reliability Mode No. 2 are based on aeration basin 2 or 5 out of service and operation of aeration basin 3 or 4 in aerobic mode. High air demands are a result of the low OTE provided by the spiral-roll diffuser configuration in basins 3 and 4.

3.0 WIRE-TO-AIR EFFICIENCY

Each available blower technology has unique mechanical/electrical components such as impellers, gear mechanisms, motors, and variable frequency drives. As such, each technology must be evaluated on the actual power draw on the system (true cost of operating machine). Wire-to-air efficiency is a measure of performance that characterizes the true cost of operating a blower. It represents the total input power required to produce a specific airflow and discharge pressure at a specific set of inlet conditions. Over the typical 20-year lifecycle of a blower, operating costs are significantly higher than initial capital costs. Therefore, the overall (wire-to-air) efficiency of the blower is an important consideration when selecting a replacement alternative. Actual wire-to-air efficiency is determined by factory testing under controlled conditions, using power meters with all field-installed components that affect power consumption connected to simulate field operation.

Currently accepted methods for determining blower efficiency (as defined in test codes ASME PTC-10 and ISO 5389) focus on the measurement of shaft power through the use of a torque meter. These methods account only for energy losses associated with the blower impeller/volute and gear mechanism. They do not measure the losses associated with the blower motor and other energy consuming blower components including variable frequency drives, electrical filters, fans, control elements, and blower cooling systems. As such, these test methods are inadequate for the determination of a blower's wire-to-air efficiency. Current efforts within the blower manufacturing and consulting engineering industries to create and adopt amendments to these test codes are expected to result in a standardized test procedure for determining wire-to-air efficiency.

Due to the limitations of the current test codes, the methods in which efficiency and power are reported vary between manufacturers, making it difficult to make an "apples-to-apples" comparison between alternatives. A high level of effort was applied in the completion of this study to ensure that the information provided in each manufacturer's preliminary proposal facilitated a consistent comparison between each technology and manufacturer.

For this study, the wire-to-air efficiencies of the existing blowers were based on factory performance test curves and the expected performance of the connected electrical equipment. Wire-to-air efficiencies of the new blower replacement alternatives were based on manufacturer's performance projections for a set of specified inlet conditions.

4.0 BLOWER TECHNOLOGY OVERVIEW

There are four blower technologies in common use today at wastewater treatment facilities: positive displacement, multi-stage, single-stage, and high-speed direct-drive (Turbo). Positive displacement blowers are far less efficient than single and multi-stage blowers. They are commonly used in lower flow and variable pressure applications. They will not be considered in this evaluation. For the purpose of comparing blower technologies, a summary of key blower parameters is provided for each technology in Table 4.1. The representative manufactures used for this comparison are as follows: Gardner-Denver/Hoffman for multi-stage blowers, Siemens Turbomachinery Solutions for single-stage blowers, and APG-Neuros for direct-drive (Turbo) blowers.

Both multi-stage and single-stage technologies are commonly used at wastewater treatment facilities throughout North America. Multi-stage blowers are generally less efficient and have less turndown capability than single-stage blowers. Single-stage blowers tend to have higher capital costs than their multi-stage counterparts.

Direct-drive (Turbo) blowers are a relatively new technology. They provide high wire-to-air efficiencies and typically have the highest associated capital costs.

Table 4.1 Comparison of Available Blower Technologies

Features	Multi-Stage	Single-Stage	Turbo
Method of Air Flow Modulation	VFD or Inlet Valve	Inlet/Discharge Vanes	VFD
Wire to Air Efficiency (%)(1)	55 - 70	65 - 75	70 - 80
Installations in North America	>600	>400	>300
Footprint	Large	Medium	Small
Noise (db)	~85	~85	<80
Capital Costs	Low	Medium	Medium-High
Operation and Maintenance(2)	High	Medium	Medium
HVAC Cooling Required(3)	Yes	Yes	Minimal

Notes:
(1) Efficiency depends on operating point of blower.
(2) Turbo blowers have been in operation for less than 10 years and long-term O&M costs have not been established.
(3) Turbo blowers discharge waste heat to process air stream.

A consideration of blower surge is important for any blower evaluation. Surge is an aerodynamic phenomenon common to blowers and is defined as the point at which the compressor cannot add enough energy to overcome the resistance within the air conveyance system. Surge causes an unstable reversal of flow that often leads to blower damage. As a safety factor, Carollo specifies a minimum surge margin for all blower designs. A surge margin (rise-to-surge) is the margin between the discharge pressure developed by the blower at a given flow and the system pressure at which blower surge develops. It is typically specified as 3.0 psi at the blower design point and 0.2 psig at the minimum blower capacity. One drawback to specifying a high rise-to-surge margin is less efficient blower operation at the design point. The advantage is more stable operation across the range of blower flows. The exact rise-to-surge margin specified depends on the specific blower technology. Some new blowers incorporate a dual-point control technology (to be discussed later) that requires a lower rise-to-surge margin for stable operation across the operating range of flows.

This study considered an adequate rise-to-surge margin for stable blower operation a critical performance requirement for the blowers (new or existing) at the Tapia WRF.

A more detailed discussion of each blower technology presented in Table 4.1 follows.

4.1 Multi-Stage Blowers

Multi-stage blowers are the least expensive of the three blower technologies evaluated, but provide the lowest wire-to-air efficiencies across their operating range of flows. They incorporate several impellers that are housed within a staged volute assembly that is directly connected to a motor. The impellers rotate at the same speed as the motor, and no gear mechanism is required. Capacity turndown is accomplished either by inlet throttling with a butterfly valve or by adjusting the drive shaft rotational speed through the use of a variable frequency drive (VFD). Typically, VFDs provide better efficiencies over the range of blower turndown than can be achieved through inlet throttling.

The capacities of multi-stage blowers range from approximately 100 to 40,000 SCFM, with discharge pressures up to 25 psig.

A number of manufacturers provide multi-stage blowers to the U.S. market, including Gardner-Denver (manufacturer of Hoffman and Lamson blowers), Continental, and HSI.

Because they offer the lowest wire-to-air efficiencies across their operating range of flows, multi-stage blowers have the highest energy usage and highest subsequent energy costs. A lifecycle cost evaluation of multi-stage blowers most often results in significantly higher ownership costs when compared to single-stage or direct-drive blower technologies. A preliminary evaluation of expected wire-to-air power requirements of new multi-stage blowers at the Tapia WRF confirmed this trend. Multi-stage blowers were not given further consideration as a replacement technology in this study.

A typical multi-stage blower installation is shown in Figure 4.1.

Figure 4.1 Typical Multi-Stage Blower Installation

4.2 Single-Stage Blowers

The majority of single-stage blowers serving in municipal applications in the U.S. were manufactured by Dresser-Roots or Siemens Turbo Machinery Solutions (previously marketed under the Turblex® trade name). Single-stage blowers typically incorporate variable inlet guide vanes (IGVs) to control blower head and flow capacity. Some single stage units incorporate dual-point control which uses variable discharge diffusers (VDDs) to vary air volume from 45 to 100 percent of capacity, and IGVs (or variable frequency drives) to independently vary blower head. The benefit provided by dual-point control is improved stability of blower operation at low rise-to-surge margins. The result is improved blower turndown, and higher efficiencies throughout the operating range of the blower.

Single-stage blowers incorporate a gear mechanism (speed increaser) between the low-speed motor shaft and the high-speed impeller shaft. This gear mechanism may be either integral to or separate from the blower impeller housing.

Single-stage blowers can achieve output flows from 500 to 70,000 SCFM at discharge pressures between 4 and 30 psig.

Due to the complexity of their associated oil cooling, gear mechanism, and inlet/discharge vane control systems, single-stage blowers tend to have higher maintenance costs than their multi-stage counterparts. Higher maintenance costs notwithstanding, because they provide significantly higher wire-to-air efficiencies, single-stage blowers generally offer lower overall operating costs than multi-stage blowers. The wire-to-air efficiencies of single-stage blowers incorporating dual-point head and flow controls can rival or surpass those provided by direct-drive (Turbo) blowers.

A modern single-stage blower is shown in Figure 4.2.

Figure 4.2 Modern Single-Stage Blower (Courtesy of Siemens)

4.3 Direct-Drive (Turbo) Blowers

Direct-drive blowers (hereafter referred to as “Turbo” blowers) incorporate a centrifugal impeller that is directly coupled to a high-speed (20,000 to 30,000 RPM) electric motor with a variable frequency drive (VFD). The blowers are compact and are manufactured as a packaged system consisting of a blower, motor, VFD, control panel, vibration isolators, and ancillary components. The packaged system is enclosed in a sound attenuating enclosure that substantially reduces noise.

Turbo blowers incorporate either an airfoil or magnetic bearing design. Airfoil bearings have several advantages over magnetic bearings in that they require no lubrication, and do not rely on a power input to charge magnetic fields.

Turbo blower drives can be either induction-type or permanent magnet synchronous motors (PMSM). PMSM motors are generally more efficient than induction motors over their operating range and are more compact resulting in a reduced footprint for the same output horsepower.

Turbo blowers range in size from 30 to 350 hp. A single Turbo blower can provide airflows up to 8,000 SCFM at typical discharge pressures of 7 to 9 psig. Several manufacturers offer dual-core models that combine two Turbo blowers within a common enclosure. Combined blower sizes of 400 to 700 hp can be achieved with a turndown range from 3,000 to 15,000 SCFM. The primary advantages offered by Turbo blower technology are:

- Small footprint and quiet operation: The small footprint can be an advantage in retrofit projects.
- High wire-to-air efficiencies over the operating range of flows
- Wide turndown range: Single-core units can achieve turndown to 45 percent of maximum flow, dual-core units can achieve turndown to 25 percent of maximum flow. The actual turndown range depends greatly on system operating conditions and the specified rise-to-surge.

A typical Turbo blower installation is shown in Figure 4.3.

Figure 4.3 Typical Turbo Blower Installation

Several manufactures that currently deliver Turbo blowers to the U.S. market include APG-Neuros, Aerzen, and Siemens Turbomachinery Solutions. A brief summary of each manufacturer follows.

4.3.1 APG-Neuros

APG-Neuros was founded in 2005 as a merger between Canada-based Aviation and Power Group (APG) and Korea-based Neuros Company LTD. Both companies have their foundations in the development of high efficiency aeronautic and power generation equipment. The first installation of a high-speed blower manufacturer by APG-Neuros was in 2005. APG-Neuros currently manufactures single-core Turbo blowers in sizes ranging from 50 to 350 hp, and dual-core Turbo blowers ranging from 400 to 700 hp. As of January 2011, APG-Neuros claimed an 80 percent U.S. market share in the Turbo blower industry, with over 330 operating Turbo blowers serving in wastewater treatment applications in the U.S. and Canada. APG-Neuros has manufacturing facilities in both the U.S. and Canada.

4.3.2 Aerzen USA

Originally manufactured in Korea under the name K-Turbo, Aerzen Turbo blowers utilize K-Turbo technology but are now manufactured by Aerzen USA Corp. Aerzen USA currently has over 40 Turbo blower installations at wastewater treatment plants within North America. The first blower installation within the U.S. incorporating this technology (K-Turbo) was in Sun River, OR, in 2008. Aerzen USA manufactures their Turbo blowers in Korea and the U.S.

4.3.3 Siemens Turbomachinery Solutions (STS)

Previously manufactured by Turblex (prior to October, 2010), STS Turbo blowers offer a proprietary Dual-Point^{TM} control system which utilizes a variable frequency drive and variable discharge diffuser to independently regulate the flow and head generated by the blower. Off-design efficiencies are improved using this system of control. The largest Turbo blower size currently offered by Siemens is 300 hp. They do not currently offer a dual-core Turbo machine. Siemens currently has 22 Turbo installations at wastewater treatment plants within North America. The motor and impeller are manufactured in Denmark. All other components are manufactured in Springfield, MO.

4.4 Single-Stage vs. Turbo Blowers

From a lifecycle cost perspective, blower replacement evaluations are commonly reduced to a choice between modern single-stage and Turbo technologies. When choosing to integrate either technology within an existing wastewater plant, consideration must be given to the overall costs of ownership. As presented in Table 4.1, the wire-to-air efficiencies of both technologies are comparable, with Turbo blowers generally holding a small advantage over conventional single-stage blowers with single-point inlet vane or VFD control. The wire-to-air efficiencies of modern single-stage blowers with dual-point control often equal or exceed those provided by Turbo blowers.

Overall maintenance costs associated with both technologies are also comparable. Maintenance of a single-stage blower is generally attributed to the replacement of consumables (i.e., air and oil filters), periodic maintenance of an oil cooling system, and periodic replacement of ceramic bearings. Maintenance costs associated with Turbo blowers are generally attributed to the replacement of consumables (e.g., air filter, coolant), and periodic replacement of electronic components such as VFDs, harmonic filters, and line reactors.

Turbo blowers utilize a high-frequency VFD that is only available in a low voltage rating. As a result, Turbo technology is limited to low voltage applications. In retrofit projects, the electrical power delivered to the existing blowers is medium voltage (as is the case at the Tapia WRF). Additionally, the high-frequency VFD utilized by Turbo blower technology produces electrical noise (harmonics) and electromagnetic pulses that can affect the operation of components within the blower package, other electrical equipment on the same grid and in vicinity of the blower. Network filter elements such as line input reactors, and harmonic filters are usually required to minimize these effects.

The capital costs associated with the electrical components (i.e., step down transformers, harmonic filters, etc.) to facilitate the requirements of Turbo technology can weight the analysis in favor of single-stage blowers.

Conversely, when capital costs associated with the required electrical components can be minimized, the reduced footprint and high wire-to-air efficiencies of Turbo blowers may weight the cost-benefit analysis in favor of this technology.

5.0 EVALUATION OF EXISTING BLOWERS

Process air for the Tapia WRF is currently provided by three constant speed, 250 hp, multistage Hoffman blowers and three constant speed, 900 hp, single-stage Roots blowers. Capacity turndown of the single-stage Roots blowers is provided by inlet guide vanes. The capacities of the multistage Hoffman blowers are not currently controlled (albeit inlet throttling valves are installed).

One Roots blower currently operates to maintain a system pressure of 7.5 psig during most of the day. During the mid-morning hours, when air demands are at a minimum, the Roots blower stops and plant air demands are satisfied by two Hoffman blowers. Occasionally, a Hoffman blower is called to supplement an operating Roots blower when plant air demands are high (early-to-mid afternoon hours). Figure 5.1 presents a graphic of typical diurnal blower flows at the Tapia WRF.

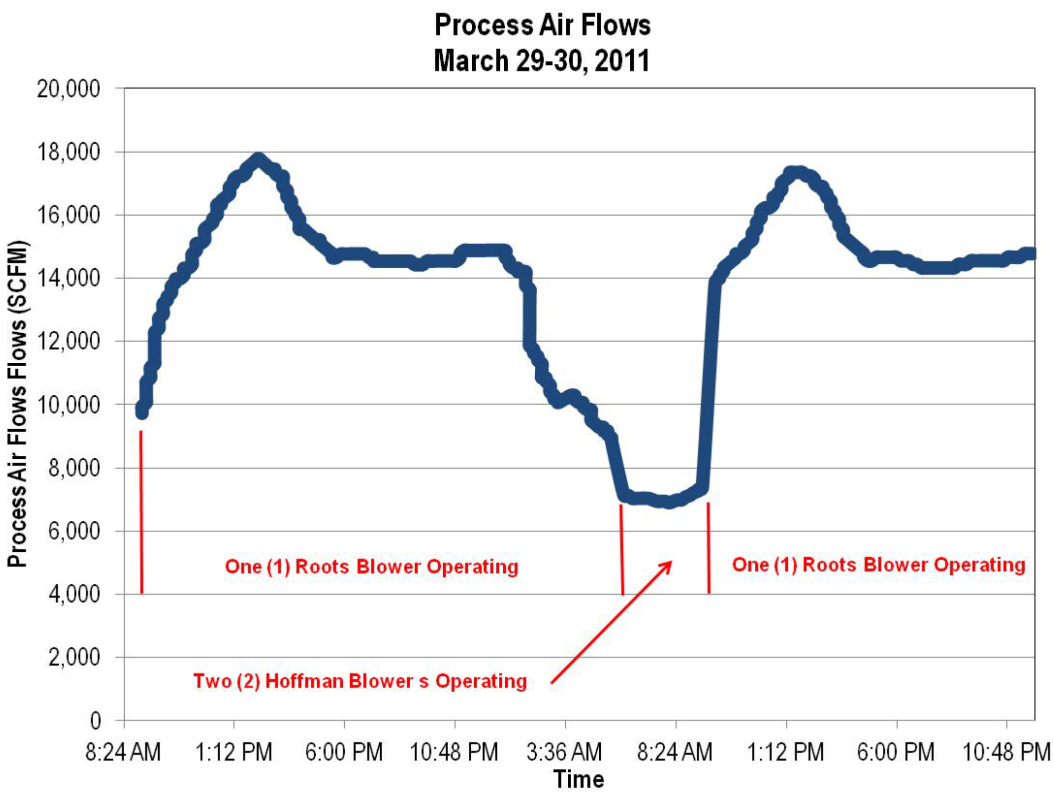

Figure 5.1 Existing Blower Airflows

Table 5.1 provides general nameplate design information related to the existing blowers.

Table 5.1 Existing Blowers - Nameplate Design Data			
Description	**Units**	**Parameter Values**	
Type	N/A	Single Stage	Multi Stage
Manufacturer	N/A	Dresser-Roots	Hoffman (Gardner-Denver)
Age	Yrs.	>30	~40
Design Conditions			
Inlet Temperature	°F	100	100
Relative Humidity	%	50	36
Barometric Pressure	psia	14.5	14.4
Blower Inlet Pressure	psia	14.3	14.2
Blower Outlet Pressure	psia	21.6	21.9
Rated Flow	SCFM	20,600	4,400
Wire-to-Air Efficiency(1)	%	65 - 71	55 - 63
Head Modulation	N/A	Inlet Guide Vanes	None(2)
Flow Modulation	N/A	Inlet Guide Vanes	None(2)
Drive Type	N/A	Separately Geared	Direct Drive
Motor			
Voltage	V	4,160	4,160
Speed	RPM	1,185	3,550
Rated Motor Output Power	hp	900	250

Notes:
(1) Expected efficiencies at rated blower inlet conditions are based on a review of data provided by the blower manufacturer. Efficiency depends on operating point of blower.
(2) Throttling valves are currently installed at the inlet to each Hoffman blower but are not currently modulated to control blower head or flows.

5.1 Existing Roots Blowers

Roots blowers No.'s 1 and 2 were installed in 1980 as part of a plant expansion that included compressed air station "A." The third Roots blower was added in 1987 as part of Reclamation Facility Expansion No. 3.

The Roots blowers (Roots model 30" OIB) have a rated capacity of 22,500 SCFM at a rated discharge pressure of 7.1 psig. The maximum capacity of these blowers at the expected future discharge pressure of 8.0 psig is 16,700 SCFM. The expected wire-to-air efficiency of these blowers is between 65 and 71 percent throughout their turndown range.

Airflows from each blower are currently measured by a venturi-tube meter installed in the downstream blower discharge piping. The venturi flow meters measure flows in the range of zero to 24,000 SCFM with a permanent pressure drop below 0.4 psig.

Based on a review of maintenance records provided by the JPA, costs associated with maintaining the Roots blowers have averaged about $8,000 annually since 2006.

A visual representation of the current Roots blower installation is provided in Figure 5.2.

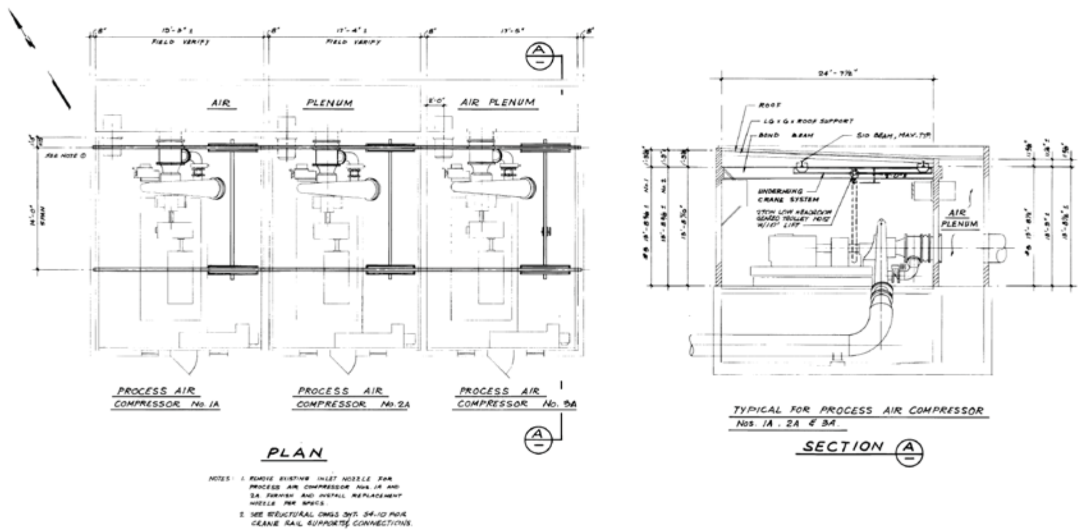

Figure 5.2 Current Roots Blower Installation (Source: RFE-III Drawings)

At a discharge pressure of 8.0 psig, these blowers can turn down to only 11,000 SCFM. Consequently, these blowers could not supply expected minimum and average airflows after the aeration basin improvements have been implemented.

Additionally, at the required discharge pressure of 8.0 psig, these blowers would not have sufficient rise-to-surge to ensure stable operation. In their present condition, the Roots blowers would not be suitable for operation at the Tapia WRF after the aeration basin improvements have been implemented.

5.2 Existing Hoffman Blowers

The existing Hoffman blowers (Hoffman model No. 38506BX) were installed in the early 1970’s as part of Reclamation Facility Expansion No. 2.

The Hoffman blowers have a rated capacity of 4,400 SCFM at a rated discharge pressure of 7.5 psig. The maximum capacity of these blowers at the expected future discharge pressure of 8.0 psig is 3,900 SCFM. Using inlet throttling valves, these blowers could reliably turndown to a flow of 2,000 SCFM at this discharge pressure.

The blowers are currently operated at 100 percent of capacity. They are equipped with inlet throttling valves, but these valves are not modulated to regulate blower flows. Flows from these blowers are calculated internally at the existing blower control panel based on system operating pressure and the blower curve.

A review of factory blower curves indicates that these blowers provide an estimated wire-to-air efficiency between 55 and 63 percent over their turndown range.

Based on a review of maintenance records provided by the JPA, costs associated with maintaining the Hoffman blowers have averaged about $600 annually since 2006.

A visual representation of the current Hoffman blower installation is provided below in Figure 5.3.

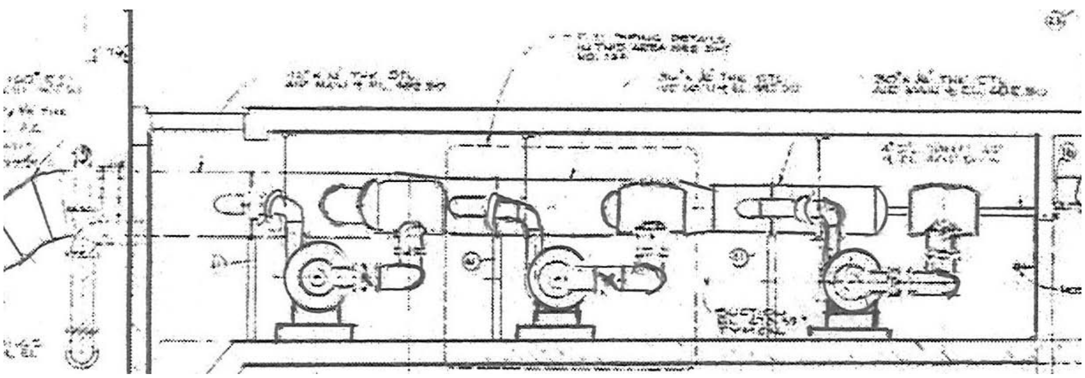

Figure 5.3 Current Hoffman Blower Installation (Source: RFE-II Drawings)

Despite their age, the Hoffman blowers have been operating reliably, as indicated by the reports of relatively low annual maintenance costs and discussions with plant operators. While these blowers are capable of satisfying current minimum and average plant air demands (as presented in Table 2.1), they cannot satisfy current or future peak air demands.

6.0 BLOWER REPLACEMENT ALTERNATIVES

6.1 Assumptions and Approach

This study assumed that the Hoffman blowers - with minor modifications such as restoring inlet throttling capability - will continue to operate reliably for an additional ten years. The Roots blowers were selected for replacement for several reasons:

1. They are incapable of providing the increased discharge pressure of 8.0 psig after the improvements to the aeration basin diffuser system.

2. They require substantially higher annual maintenance costs than the existing Hoffman blowers.

3. Retaining the existing Hoffman blowers for an initial ten-year period will facilitate the staging of the Roots blower replacement project. Staging the blower replacement project will reduce total lifecycle costs.

During the blower replacement project's initial ten-year period, the new blower(s) will provide high efficiency production of air up to normal peak plant flows. The existing Hoffman blowers will serve as standby units should a new blower require maintenance and will provide additional airflows to facilitate plant "Reliability" modes of operation. After the initial ten-year period, it is assumed that the Hoffman blowers will require decommissioning due to failure and/or high maintenance costs. At that time, additional Roots blower(s) would be replaced to provide the airflows required to satisfy peak air demands during normal plant operation, and to serve as standby units should a blower require maintenance.

A discussion of feasible alternatives for replacing the Roots blowers follows.

6.2 Feasible Blower Alternatives

Three alternatives for replacing the existing Roots blowers were selected for a detailed evaluation. The two technologies represented by these alternatives are single-stage and Turbo blowers. As previously discussed, multi-stage blower technology was eliminated from further evaluation due to high operating costs. Additional consideration was given to rebuilding the existing Roots blowers to satisfy future airflow turndown and discharge pressure requirements. Due to the high capital costs associated with this option (approximately $600,000 per blower, not including construction/engineering costs) it received no further consideration. The selected alternatives are described below. Expected current (Yr-0) and future (Yr-20) plant airflows assume that the aeration basin spiral-roll diffuser system will be replaced with a full-floor cover system.

Regardless of the blower technology selected, minor modifications to the plant air conveyance system will be required to connect the discharge piping from the new blowers to the existing plant air piping. The existing venturi flow meters serving the Roots blowers can be retained.

Each of the alternatives evaluated can be readily staged to facilitate the aeration basin diffuser system improvements.

6.3 Description of Blower Replacement Alternatives

6.3.1 Alternative 1 - New Single-Stage Technology

The blower manufacturer selected for this alternative was Siemens Turbomachinery Solutions (STS).

6.3.1.1 Project Year 0 Improvements

At project year 0, two existing Roots blowers would be replaced by two 350 hp integrally-geared single-stage blowers (Siemens KA10). Each new blower would provide a flow capacity of approximately 8,150 SCFM. Average air demands would be satisfied by operating one new blower. Two new blowers would satisfy peak air demands during normal plant operation. Redundancy - should a new blower require maintenance - would be provided by the existing Hoffman blowers. Plant air demands during operation in “reliability” modes (discussed in TM-1) would be satisfied by operating two new blowers and two existing Hoffman blowers.

6.3.1.2 Project Year 10 Improvements

At project year 10, the remaining Roots blower would be replaced by an additional new single-stage blower. Peak air demands during normal plant operation would be satisfied by operating two blowers. The third new blower could be operated to satisfy peak air demands when the plant is operated in a “reliability” mode.

The Siemens KA10 blower represents Siemens’ response to the recent trend toward standardization of blower components, resulting in significantly reduced manufacturing costs. Siemens also manufactures a larger blower from non-standard components - the KA22. The KA22 can provide greater flows but at a significantly higher capital cost.

A chart showing expected air demands and blower capacities for Alternative 1 is presented in Figure 6.1. In this figure, plant air demands are presented as horizontal dashed lines. Blower capacities are represented by vertical columns.

Figure 6.1 indicates that, for Alternative 1, blower capacities will remain generally constant over the 20-year project lifecycle. The third new blower installed at year 10 will replace the flows previously provided by the decommissioned Hoffman blowers.

All normal peak air demands can be satisfied with the largest blower out of service for maintenance.

Figure 6.2 presents a three dimensional concept of Alternative 1.

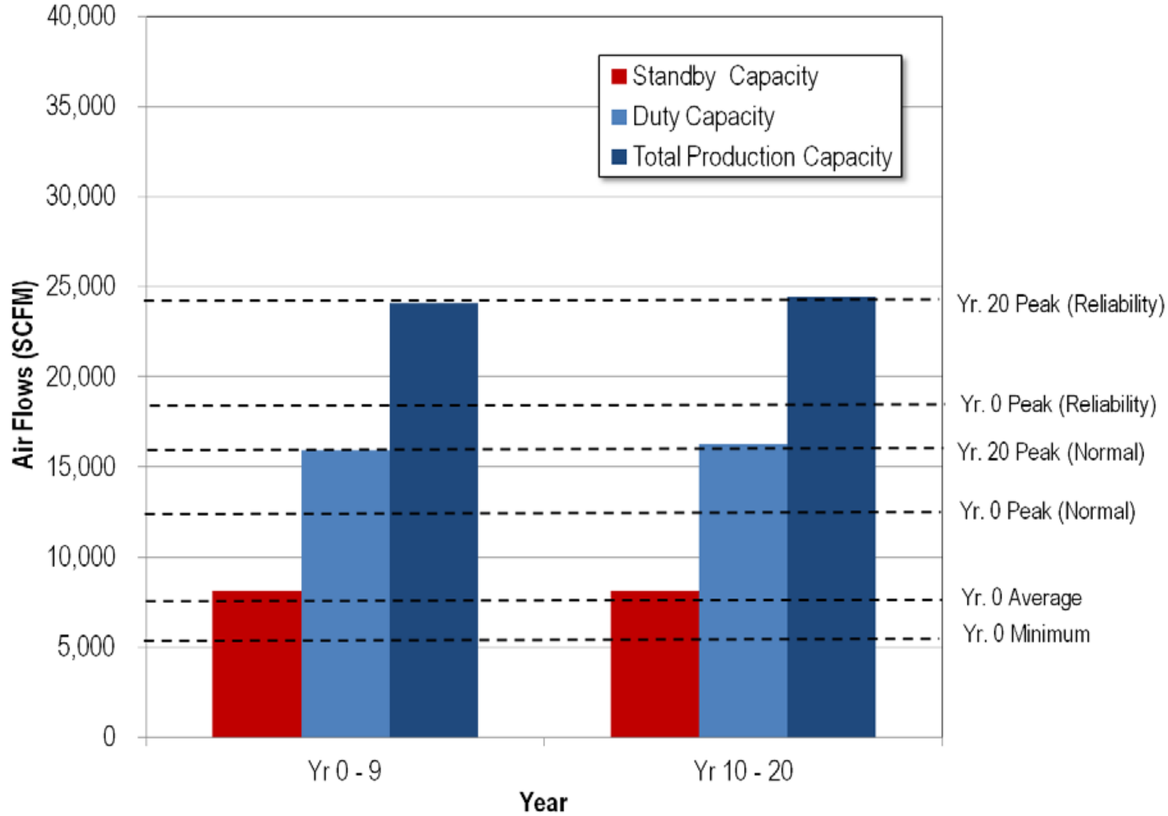

Figure 6.1 Alternative 1 - Blower Capacities

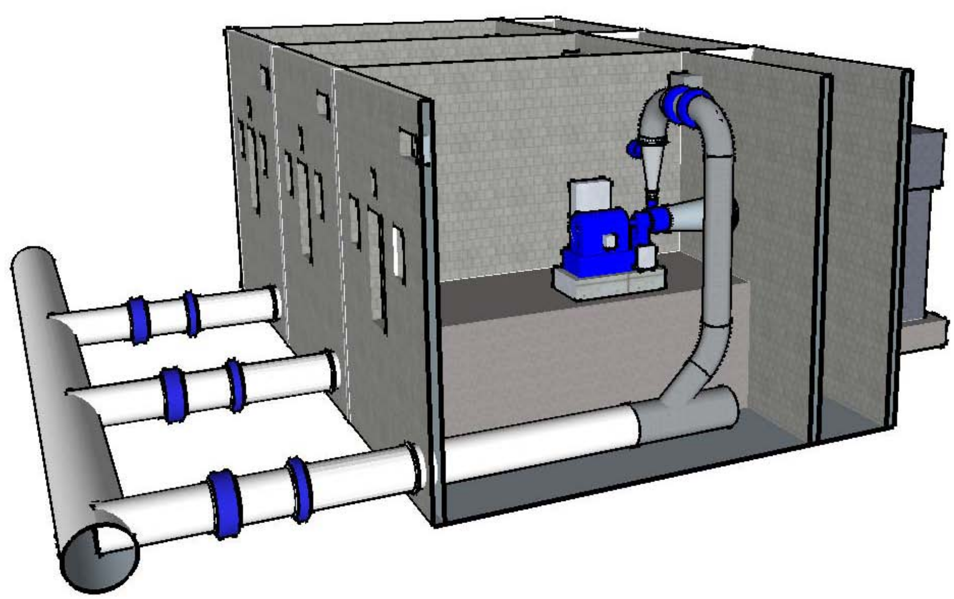

Figure 6.2 Alternative 1 - 3D Concept

6.3.2 Alternative 2 - New Turbo Technology (Single-Core)

The blower manufacturer selected for this alternative was APG-Neuros.

6.3.2.1 Project Year 0 Improvements

At project year 0, two existing Roots blowers would be replaced by two 350 hp single-core Turbo blowers (Neuros NX350). Each new blower would provide a flow capacity of approximately 7,600 SCFM each. Average air demands would be satisfied by operating one new blower. Two new blowers would satisfy peak air demands during normal plant operation. Redundancy - should a new blower require maintenance - would be provided by the existing Hoffman blowers. Plant air demands during operation in "reliability" modes would be satisfied by operating two new blowers with two Hoffman blowers.

6.3.2.2 Project Year 10 Improvements

At project year 10, the remaining existing Roots blower would be replaced by an additional 350 hp Turbo blower. Peak air demands during normal plant operation would be satisfied by operating two Turbo blowers. The third Turbo blower could be operated to satisfy peak air demands during operation of the plant in a "reliability" mode.

The 350 hp blower is the largest single-core machine manufactured by APG- Neuros. This is also the largest turbo blower available that is equipped with airfoil bearings.

A chart showing expected air demands and blower capacities for Alternative 2 is presented in Figure 6.3. In this figure, plant air demands are presented as horizontal dashed lines. Blower capacities are represented by vertical columns.

Figure 6.3 indicates that the blower capacities provided by Alternative 2 will be slightly reduced at project year 10. This is based on the assumption that the existing Hoffman blowers must be decommissioned and a third Turbo blower installed at that time. The flow produced by a third Turbo blower (7,600 SCFM) is slightly less than that produced by two operating Hoffman blowers (7,800 SCFM). Consequently, the capacity of two Turbo blowers will be about 1,200 SCFM less than normal peak air demands at project year 20.

Figure 6.4 presents a three dimensional concept of Alternative 2.

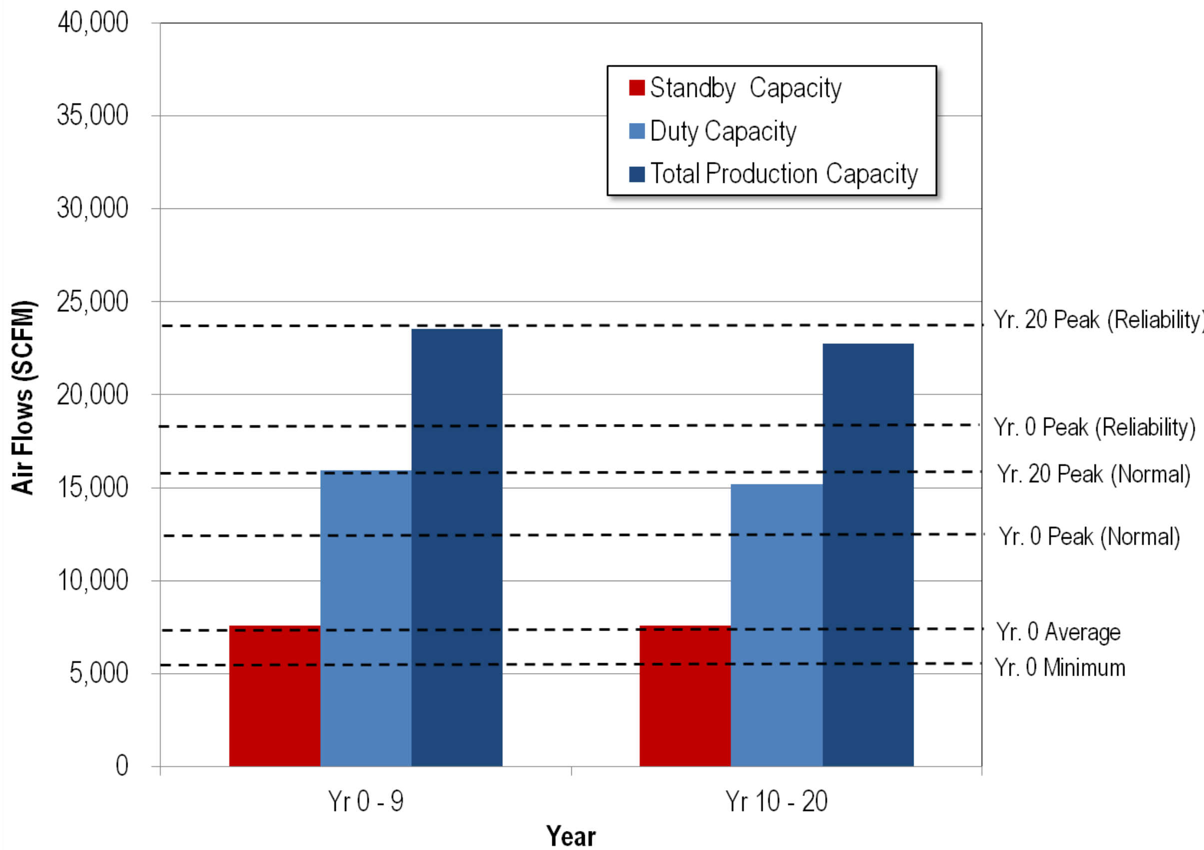

Figure 6.3 Alternative 2 - Blower Capacities

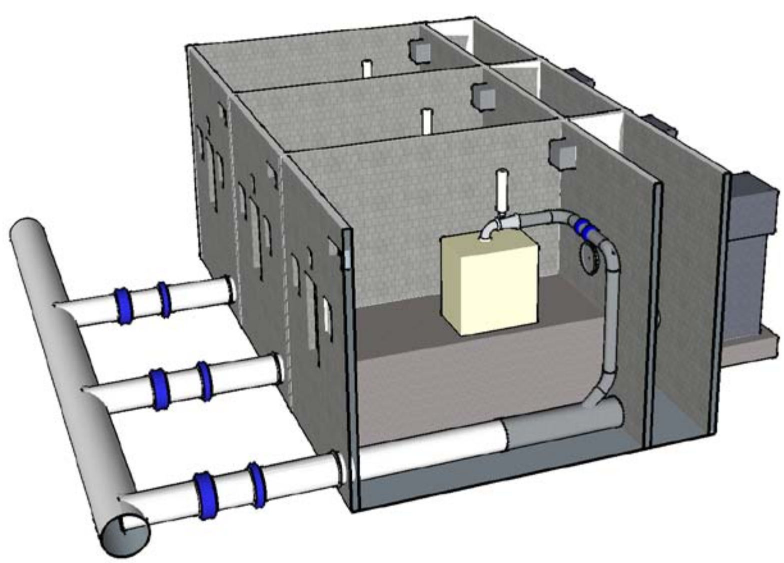

Figure 6.4 Alternative 2 - 3D Concept

6.3.3 Alternative 3 - New Turbo Technology (Dual-Core)

The blower manufacturer selected for this alternative was APG-Neuros.

6.3.3.1 Project Year 0 Improvements

At project year 0, one existing Roots blower would be replaced by one 700 hp dual-core Turbo blower (Neuros NX700). This blower is essentially two 350 hp Turbo blowers ("cores") installed in a common enclosure. Each blower core will provide a flow capacity of approximately 7,500 SCFM. Peak air demands during normal plant operation through project year 10 will be satisfied by operating both new Turbo blower cores. The existing Hoffman blowers would function as standby units should a blower core require maintenance. Plant air demands during operation in "reliability" modes would be satisfied by operating two Hoffman blowers to supplement the production of two Turbo blower cores.

6.3.3.2 Project Year 10 Improvements

At project year 10, a second Roots blower would be replaced by an additional 700 hp dual-core Turbo blower. Peak air demands during normal plant operation would be satisfied by operation of three Turbo blower cores. The fourth Turbo blower core could be operated to satisfy peak air demands during operation of the plant in "reliability" mode.

The 700 hp dual-core Turbo machine facilitates significantly higher flow capacities and turndown than the 350 hp single-core Turbo blower with a relatively small increase in blower footprint. The Roots blower building provides ample space for the installation of the 700 hp Turbo machines.

A chart of expected air demands and installed blower capacities for Alternative 3 is presented in Figure 6.5. In this figure, plant air demands are presented as horizontal dashed lines. Blower capacities are represented by vertical columns.

Figure 6.5 indicates that blower capacities provided by Alternative 3 will be significantly increased at project year 10. Standby blower capacities will remain essentially constant over the 20-year project life. Year 20 normal peak air demands will be satisfied by operating three blower cores. Year 20 "reliability" peak air demands will be met by four operating cores.

Figure 6.6 presents a three dimensional concept of Alternative 3.

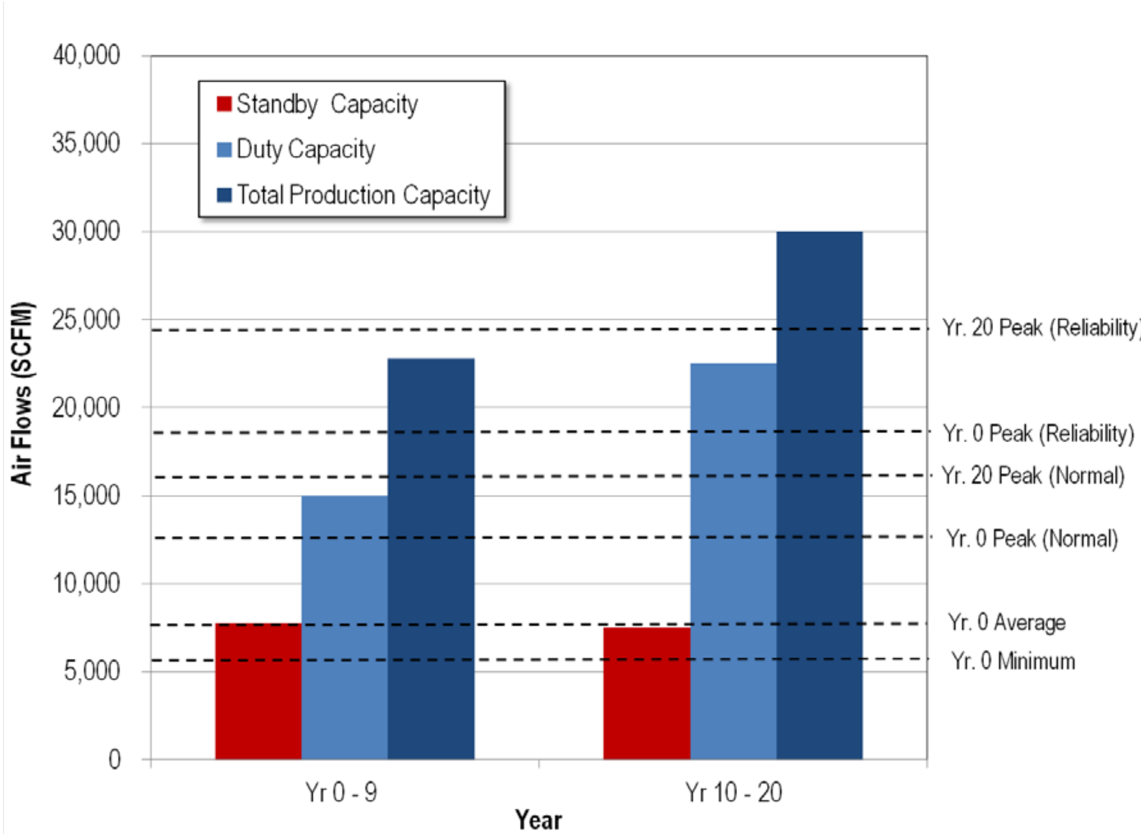

Figure 6.5 Alternative 3 - Blower Capacities

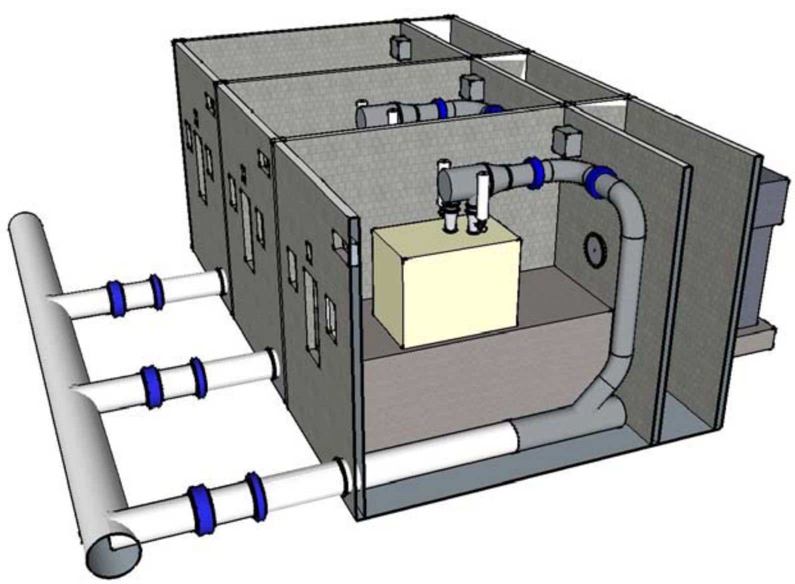

Figure 6.6 Alternative 3 - 3D Concept

6.4 Evaluation Criteria

The three blower replacement alternatives were evaluated based on the following criteria:

1. Ability of blowers to satisfy process requirements, including:
   a. Providing required airflows with no “gaps” in air flow capacities
   b. Providing sufficient blower redundancy - ability to satisfy normal peak air demands with the largest unit out of service for maintenance
   c. Providing sufficient rise-to-surge margin to facilitate stable blower operation at all flows

2. Compatibility of blowers with existing blower room facilities, including:
   a. Ability of blowers to maximize available floor space
   b. Required level of modification to the existing infrastructure (air conveyance piping, valves, electrical, building structure, etc.)

3. Initial capital costs, including costs of the following:
   a. Blower
   b. Blower and aeration system control panel(s)
   c. Modifications to existing mechanical and electrical infrastructure

4. Total lifecycle cost of ownership (calculated as present worth)
   a. Lifecycle cost of ownership is affected by several factors:
      - Capital costs
      - Annual operating costs
        - Energy costs
        - Maintenance costs

The annual energy costs associated with each alternative were based on expected wire-to-air efficiencies. Wire-to-air efficiencies were determined based on performance projections provided by blower manufacturers and the expected efficiencies of connected electrical components such as motors and variable frequency drives.

6.5 Evaluation of Alternatives

Each selected alternative was evaluated based on the criteria presented above.

1. *Ability to Satisfy Process Requirements*

   Each alternative is capable of satisfying the expected current and future normal plant air demands after the aeration basin improvements have been implemented.

For each alternative evaluated, a standby blower must be operated to satisfy future peak air demands during operation of the plant in a “reliability” mode.

Each blower alternative provides a sufficient rise-to-surge margin for stable operation across its range of operating flows. Alternatives 2 and 3 (Turbo technology) provide a rise-to-surge margin of 3.0 psig at the rated design condition. Alternative 1 (single-stage technology) provides a rise-to-surge margin of 0.2 psig across the range of blower flows. This lower rise-to-surge margin is appropriate for the dual-point control scheme implemented by Siemens, and results in improved efficiencies over the range of operating flows.

2. *Compatibility with Existing Blower Room Facilities*

Each of the evaluated alternatives will physically fit within the existing Roots blower building. Capital costs associated with modifications to the existing air conveyance piping within these rooms are minimal for all three alternatives.

Each of the alternatives will require several modifications to the plant’s existing electrical infrastructure.

Alternative 1 would require the following additional electrical components:

- Installation of new motor starters
- Installation of new conductors between the motor starters and existing medium voltage switchgear
- Installation of conductors between the new motor starters and blowers

Alternatives 2 and 3 (Turbo blowers) would require the following additional electrical components, including:

- Installation of new step-down transformers to provide the 480-volt power required by the Turbo blower drives.
- Installation of new conductors between the transformers and existing medium voltage switchgear
- Installation of conductors between the new transformers and blowers

These electrical modifications will contribute significantly to the project’s capital costs. The costs of blower-related electrical modifications for Alternative 1 (single-stage technology) are expected to be approximately $120,000. The costs of blower-related electrical modifications for Alternatives 2 and 3 (Turbo technology) are estimated to be approximately $220,000 and $180,000, respectively.

3. *Comparison of Initial Capital Costs*

Estimated initial (Yr-0) capital costs for each alternative are shown by the chart presented in Figure 6.7. Capital costs of the blowers and modifications to the air conveyance system are shown separately from the costs related to electrical and control modifications.

The cost estimates for each alternative assume that a local control panel will be provided at each blower. Additionally, a new master control panel will be provided to replace the existing blower and aeration system control panels. Improvements to the blower and aeration system controls are discussed in more detail in the following section. The costs of these improvements to the aeration and blower system controls are included in the electrical /control costs shown in Figure 6.7.

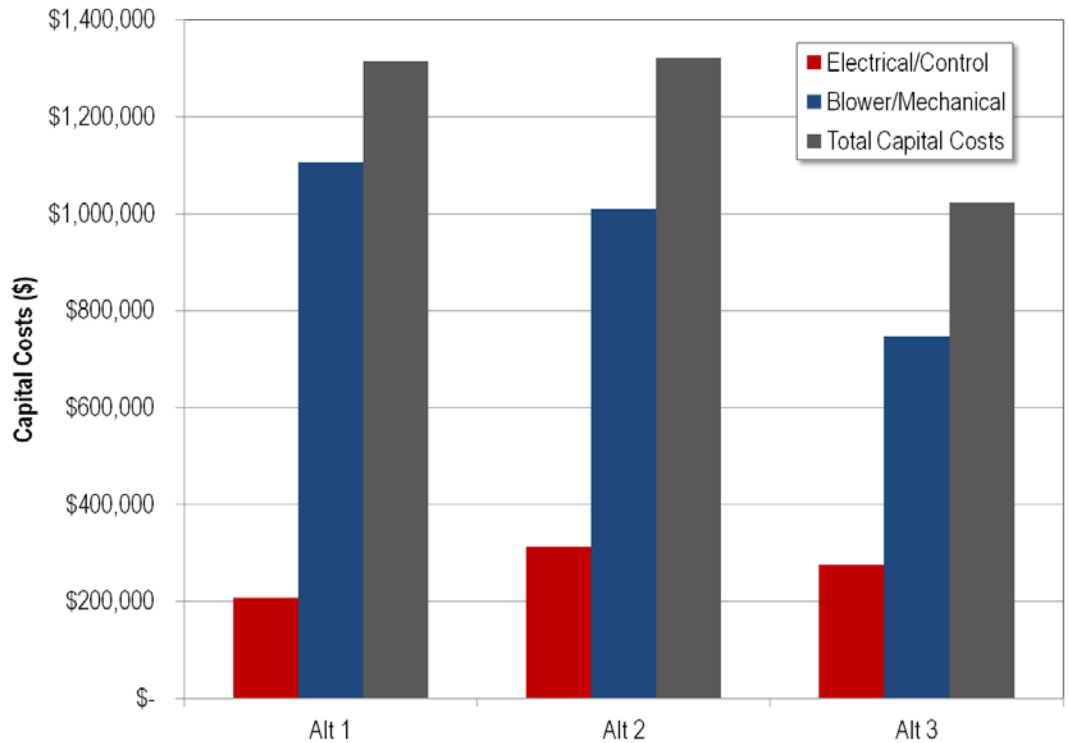

Figure 6.7 Capital Costs Comparison

Figure 6.7 indicates that Alternatives 2 and 3 (Turbo technology) have higher capital costs related to electrical/control modifications than Alternative 1 (single-stage technology).

Alternative 3 has the lowest capital costs related to blowers and associated mechanical modifications. Alternative 3 incorporates two 350 hp blower cores into a single enclosure. The combined dual-core blower costs significantly less than two separate 350 hp blowers. Consequently, Alternative 3 represents the lowest capital cost blower replacement alternative.

Detailed capital cost breakdowns for each alternative are provided in Appendix A. Estimated capital costs include a sales tax of 9.8 percent and a contingency of 10 percent, as well as 12 percent for contractor overhead and profit. Also included is 15 percent for engineering, legal, and administration fees as well as a 5 percent owner's reserve for change orders.

4. *Comparison of Lifecycle Costs of Ownership*

Lifecycle costs for each alternative were calculated as 20-year present worth. The calculation of lifecycle costs considered the following:

- Capital costs (both project year 0 and 10)
- Annual operating costs, consisting of the following:
  - Expected annual energy costs
  - Expected annual maintenance costs

Annual energy costs for each blower alternative are compared graphically in Figure 6.8. Energy costs include an annual energy rate escalation of 3 percent. Figure 6.8 indicates that Alternative 1 (single-stage technology) provides the lowest energy costs over the lifecycle of the project. The annual energy costs associated with Alternative 1 at project year 0 are approximately $10,000 less than those associated with Alternatives 2 and 3. The explanation for the lower energy costs associated with Alternative 1 is the higher wire-to-air efficiency provided by dual-point control of head and flow.

Maintenance costs for each blower replacement alternative are comparable - between $1,300 and $3,000 during the first year of operation.

Lifecycle costs of ownership for each alternative are presented in Figure 6.9. This figure indicates that lifecycle cost of ownership are comparable for each alternative, with Alternatives 1 and 3 providing slightly lower lifecycle costs than Alternative 2. A detailed breakdown of lifecycle costs for each alternative is provided in Appendix B. The calculation of lifecycle costs assumes a discount rate of 6% for the life of the blowers.

Table 6.1 presents an evaluation matrix that summarizes the findings of the blower study. The project year-0 (calendar year 2012) energy cost savings presented in Table 6.1 were based on the performance of the existing Hoffman blowers as a baseline. As previously discussed, the existing Roots blowers cannot provide the necessary turndown and blower discharge pressures after the aeration basin improvements have been implemented. It was assumed that, under a blower replacement "do nothing" scenario, the existing Hoffman blowers could operate to satisfy average plant air demands through project year 20 (calendar year 2032).

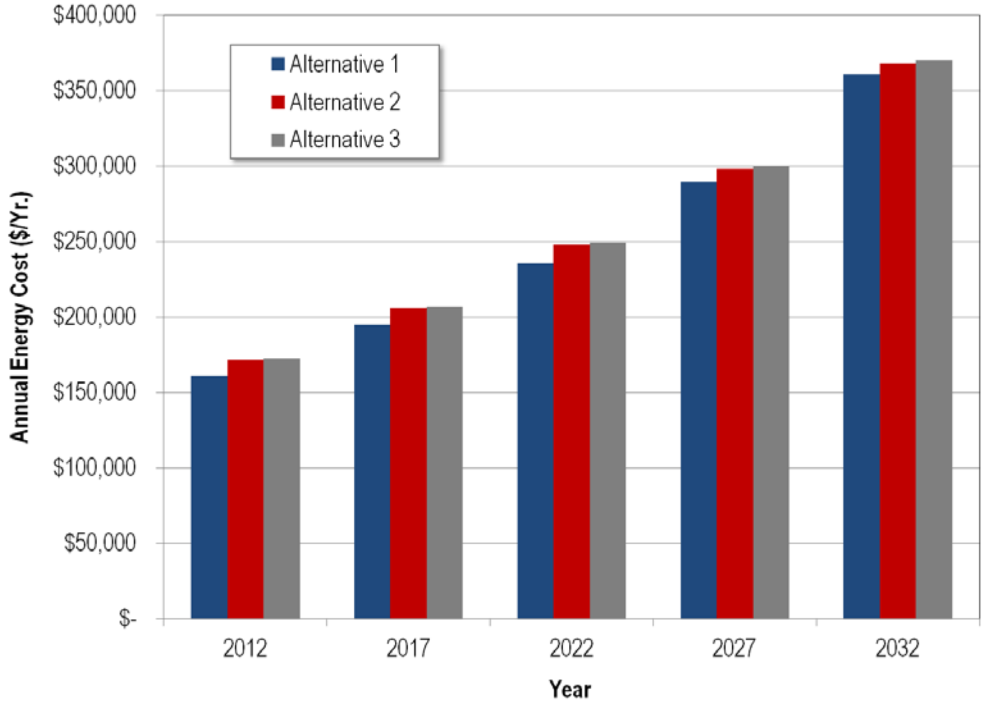

Figure 6.8 Annual Energy Cost Comparison

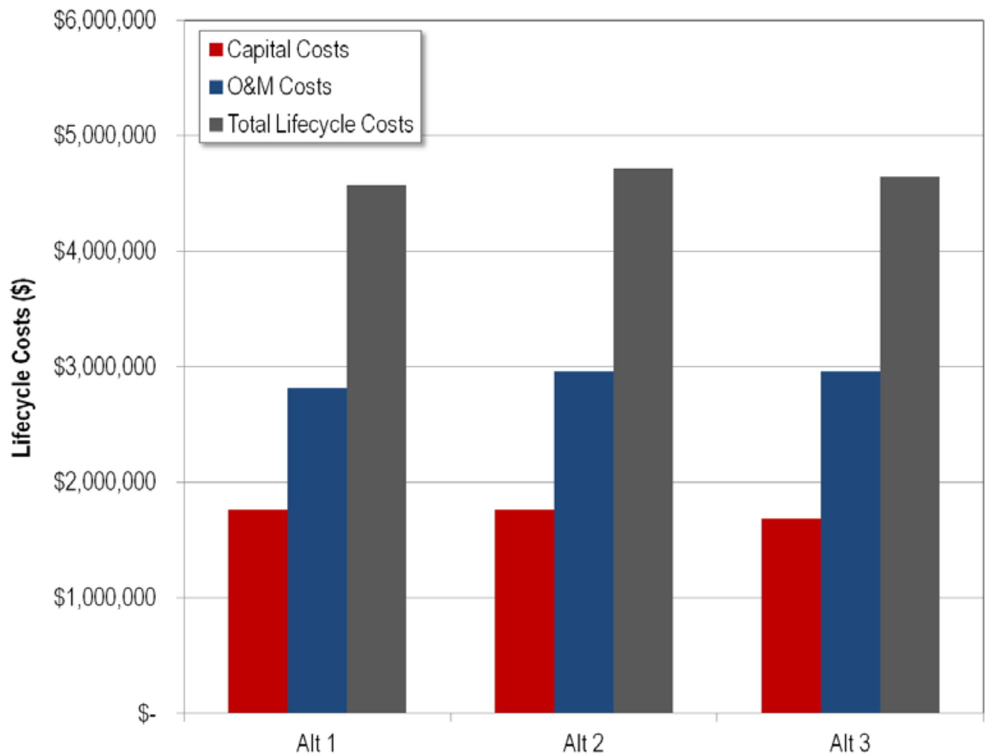

Figure 6.9 Lifecycle Costs Comparison

Table 6.1 Blower Evaluation Matrix

Description	Alternative 1	Alternative 2	Alternative 3
Blower Technology	Single-Stage	Turbo	Turbo
Blower Make/Model	Siemens KA10	Neuros NX350	Neuros NX700
Rated Blower Input Power (hp)	350	350	350
No. Blowers Provided at Project Year 0	2	2	2
Rise to Surge Margin at Design Flows (psi)	0.2	3.0	3.0
Maximum Flow per Blower (SCFM)	8,150	7,600	15,000
New Blower Capacity at Project Year 0 (SCFM)	16,300	15,200	15,000
Total Plant Air Capacity at Project Year 0 (SCFM)	24,100	23,000	22,800
Total Plant Air Capacity at Project Year 10 (SCFM)	24,450	22,800	30,000
Expected Wire-to-Air Efficiency at Yr-0 Average Flows (%)	78.2	73.4	73.0
Estimated Yr- 0 Project Capital Costs ($)(1)	$1,315,148	$1,322,188	$1,022,413
Yr-0 Capital Cost per Installed SCFM	$80.68	$86.99	$68.08
Yr. 0 Expected Annual Energy Costs ($/Yr)(2)	$160,900	$171,500	$172,400
Yr. 0 Expected Annual Energy Cost Savings(3)	$69,300	$58,800	$57,800
Simple Payback Period (Yrs)	18.9	22.5	17.7
Expected 20-yr Lifecycle Cost of Ownership ($)(4)	$4,578,000	$4,720,000	$4,650,000
Level of Required Mechanical Infrastructure Modifications	Medium	Medium	Low
Level of Required Electrical Infrastructure Modifications	Low	High	Medium

Notes:

(1) Capital costs include contractor overhead and profit, contingency, and engineering and legal fees.

(2) Annual operating costs include maintenance costs and energy costs at annual average flows and average outside air temperature of 63.5 °F and relative humidity of 58 percent.

(3) Year 0 energy costs savings were calculated against a baseline of Hoffman blower operation to achieve Yr. 0 annual average flows.

(4) Lifecycle ownership costs are shown as 20-year present worth and include expected capital costs for project year 10 improvements. Energy costs include an annual energy rate escalation of 3 percent.

Table 6.1 indicates that Alternative 3 provides the lowest capital cost per installed SCFM of new blower capacity. This alternative also provides the shortest simple payback period at 17.7 years. On the other hand, Alternative 1 provides the maximum annual energy savings and lowest 20-year lifecycle ownership costs of the alternatives evaluated.

7.0 AERATION SYSTEM CONTROLS IMPROVEMENTS

Several improvements to the aeration system controls were included in the capital costs of each blower replacement alternative:

- Replacement of existing blower control panels CCP-A and CCP-B with a new aeration system master control panel (MCP).
- Addition of local control panels (LCPs) at individual blowers.
- Addition of most-open-valve (MOV) plant air header pressure control.

A discussion of each improvement follows.

7.1 Aeration System Master Control Panel

The existing aeration system control panels (CCP-A and CCP-B) are aging and do not represent current standards in aeration system control technology. Both control panels were installed in 1987 as part of Reclamation Facility Expansion III.

Control panel CCP-A serves the existing Roots blowers and is located in the electrical room adjacent to the backup generators near the plant headworks. It controls the functions of all three existing Roots blowers and serves as the central point of control for plant air system pressure and blower operating sequence. Control panel CCP-B serves the existing Hoffman blowers and the aeration basin airflow control valves and is located in an electrical room above the Hoffman blowers near the primary sedimentation tanks. This control panel also monitors dissolved oxygen (DO) levels and airflows within the aeration basins and controls the positions of the airflow control valves at each aeration basin to maintain DO setpoints.

The proposed new aeration system master control panel (MCP) would replace both of these panels, and would be located where control panel CCP-B currently stands - near to the aeration basins. The MCP would perform the following functions:

- Control lead/lag/standby operating sequence of blowers
- Communicate with individual blower local control panels (LCPs) to modulate vane positions and/or motor speed to maintain air system pressure setpoint
- Control and monitor the aeration basin airflows to maintain a setpoint DO level in each basin
- Control operation of air system emergency surge blow-off valve(s)
- Communicate with the plant's SCADA system

A new aeration system master control panel will be critical to ensure stable and efficient control of the plant's process air system.

7.2 Blower Local Control Panels (LCPs)

The current standard of care in the wastewater blower industry is to provide a local control panel (LCP) at each operating machine. The blower LCPs perform the following functions:

- Control the blower startup and shutdown sequence
- Monitor critical blower performance parameters such as bearing temperature and vibration
- Indicate blower alarm conditions locally
- Optimize blower speed and/or vane position - programming resides on LCP's programmable logic controller (PLC)
- Facilitate local operation of machine in manual (hand) mode
  - Provide system reliability should aeration system MCP fail
  - Manual adjustment of blower speed and/or vane position
- Communicate with aeration system MCP

Most manufacturers of modern single-stage and Turbo blowers provide local control panels with their machines as a standard option. As previously mentioned, the cost estimates for each blower replacement alternative includes the cost of local control panels at each blower.

7.3 Most Open Valve (MOV) Air Header Pressure Control

The pressure within the blower discharge header(s) is currently a manually adjusted setpoint. The pressure setpoint is usually selected to account for pressure losses within the aeration diffusers and plant air conveyance piping during peak demand periods. During off-peak periods, however, this pressure setpoint is in excess of what is required to maintain the DO setpoint in the aeration basins. Consequently, the aeration basin airflow control valves must "burn" this excess pressure and energy is wasted. Most Open Valve (MOV) pressure control is basically a variable header pressure control scheme in which the blower discharge header pressure is automatically adjusted to ensure the valve at the most pneumatically-demanding location is fully open. This reduces energy waste created by valve throttling. A reduction in pressure of only 0.2 psig - from 8.0 to 7.8 psig - will result in an energy savings of approximately 2 percent.

MOV aeration control is (generally) most successfully implemented by the selected blower manufacturer. The selected blower manufacturer provides the control valves, valve operators, flow meters, DO probes, and required PLC programming.

Both APG-Neuros and Siemens Turbomachinery Solutions have extensive experience with MOV aeration control and are capable of providing a fully operational system. The aeration system components necessary for MOV control have been included in the cost estimates for the improvements discussed within this study. An additional cost of about $10,000 would be required for a blower manufacturer's trained technician to startup and tune the control system. In addition to MOV control mode, the aeration system would also be capable of operating in the current fixed air pressure control scheme.

8.0 SUMMARY AND RECOMMENDATIONS

Based on the analysis presented above, we recommend blower replacement Alternative 1. This alternative would replace two existing Roots blower at project year 0 with two new 350 hp single-stage blowers. The Siemens model KA10 was the blower evaluated for this alternative. This alternative provides the maximum annual energy savings and lowest 20-year lifecycle costs of ownership. The single-stage technology provided by Alternative 1 represents a sustained track record of reliability and predictable maintenance costs.

As described in this memorandum, several improvements to the aeration system controls are recommended. These include the following measures:

- Replacement of the existing blower and aeration system control panels CCP-A and CCP-B with a new master control panel located where CCP-B currently stands
- Addition of local control panels at the existing Hoffman blowers
- Integration of Most Open Valve (MOV) air header pressure control

These improvements to the aeration system controls are expected to reduce energy costs, increase plant reliability, and provide maximum flexibility of the aeration system. The costs of these improvements have been included in the capital cost estimates presented within this study.

The blower replacement project can be readily staged to facilitate the aeration basin diffuser system improvements. The initial (project year 0) replacement of two existing Roots blowers should occur prior to the aeration basin improvements. The remaining Roots and Hoffman blowers would satisfy the current high air demands until the new diffusers are installed. The last remaining Roots blower would be replaced at (approximately) project year 10.

A summary of blower replacement Alternative 1 is provided in Table 8.1.

Table 8.1 Blower Replacement Summary - Alternative 3

Description	Units	Parameter Values
Blower Technology	N/A	Single-Stage
Manufacturer/Model	N/A	Siemens/KA10
Wire-to-Air Efficiency[1]	(%)	75 - 78
Yr-0 Capital Costs	($)	1,315,150
Expected Year-0 Energy Cost Savings	($)	69,300
Simple Payback Period	(Yr)	19.0

Notes:
(1) Expected efficiencies are based on review of data provided by blower manufacturer. Efficiency depends on operating point of blower.

Appendix A

BLOWER REPLACEMENT COST ESTIMATING DATA

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PROJECT SUMMARY

Project:	**Tapia WRF - Blower Replacement (Alternative 1)**	**Estimate Class:**	
Client:	**Las Virgenes Municipal Water Disctrict**	**PIC:**	
Location:	**Calabasas, CA**	**PM:**	
Zip Code:	**91302**	**Date:**	**November 9, 2011**
Carollo Job #	**8578B.00**	**By:**	**Don DeMichele**
		Reviewed:	

NO.	DESCRIPTION			TOTAL
01	Mechanical			$675,364
02	Electrical			$126,792
				$0
				$0
				$0
				$0
				$0
				$0
				$0
		TOTAL DIRECT COST		**$802,156**
	Contingency		10.0%	$80,216
		Subtotal		**$882,372**
	General Contractor Overhead, Profit & Risk		12.0%	$105,885
		Subtotal		**$988,256**
	Escalation to Mid-Point		1.0%	$9,883
		Subtotal		**$998,139**
	Sales Tax (Based on)		9.8%	$97,818
		Subtotal		**$1,095,956**
	Bid Market Allowance		0.0%	$0
	TOTAL ESTIMATED CONSTRUCTION COST			**$1,095,956**
	Engineering, Legal & Administration Fees		15.0%	$164,393
	Owner's Reserve for Change Orders		5.0%	$54,798
	TOTAL ESTIMATED PROJECT COST			**$1,315,148**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

DETAILED COST ESTIMATE

Engineers...Working Wonders With Water®

Project: Tapia WRF - Blower Replacement (Alternative 1)
Client: Las Virgenes Municipal Water Disctrict
Location: Calabasas, CA
Element: 01 Mechanical

Date : November 9, 2011
By : Don DeMichele
Reviewed: 0

SPEC. NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL	TOTAL
	Division 02 - Site Construction					
02220	30" Metal Pipe, Rem From Bldg Or Process Area	60	LF	$75.36	$4,522	
	Total					**$4,522**
	Division 11 - Equipment					
11000	Single-Stage Blower (Siemens 350 hp)	2	EA	$285,000.00	$570,000	
	Total					**$570,000**
	Division 15 - Mechanical					
15112	20" 150# Fxf Awwa Butterfly Valve, No Op	2	EA	$3,336.77	$6,674	
15112	Add For Motor Operator 12" Through 20"	2	EA	$4,220.00	$8,440	
15114	20"- 125# Di Fxf Swing Check Valve	2	EA	$24,443.16	$48,886	
15252	20"A-53 Wld Steel 3/8" (Std) Wall Pipe In A Bldg	60	LF	$247.00	$14,820	
15252	30" A-53 Wld Steel 3/8" (Std) Wall Pipe In A Bldg	60	LF	$367.04	$22,022	
	Total					**$100,842**
	Grand Total					**$675,364**

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DETAILED COST ESTIMATE

Project: Tapia WRF - Blower Replacement (Alternative 1)
Client: Las Virgenes Municipal Water Disctrict
Location: Calabasas, CA
Element: 02 Electrical

Date : November 9, 2011
By : Don DeMichele
Reviewed: 0

SPEC. NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL	TOTAL
16000	#6 AWG 5KV-133% MV-105 Cable	600	LF	$4.01	$2,405	
16000	#6 AWG 5KV-133% MV-105 Cable Terminations	24	EA	$131.87	$3,165	
16000	#6 AWG XHHW-2 Cable	200	LF	$1.83	$365	
16000	#6 AWG XHHW-2 Terminations	8	EA	$20.55	$164	
16000	350HP, 5kV Motor Starter	2	EA	$33,549.00	$67,098	
16000	Control Wiring to new MCP	1	LF	$10,000.00	$10,000	
16000	LCP's for Existing Blowers (HOA, Start/Stop)	3	EA	$2,000.00	$6,000	
16000	Master Control Panel	1	EA	$40,000.00	$40,000	
	Total					**$126,792**
	Grand Total					**$126,792**

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PROJECT SUMMARY

Project:	**Blower Replacement (Alternative 2)**	**Estimate Class:**	
Client:	**Las Virgenes Municipal Water District**	**PIC:**	
Location:	**Calabasas, CA.**	**PM:**	
Zip Code:	**91302**	**Date:**	**November 9, 2011**
Carollo Job #	**8578B.00**	**By:**	**Don DeMichele**
		Reviewed:	

NO.	DESCRIPTION			TOTAL
01	Mechanical			$616,045
02	Electrical			$190,405
				$0
				$0
				$0
				$0
				$0
				$0
		TOTAL DIRECT COST		**$806,450**
	Contingency		10.0%	$80,645
		Subtotal		**$887,095**
	General Contractor Overhead, Profit & Risk		12.0%	$106,451
		Subtotal		**$993,547**
	Escalation to Mid-Point		1.0%	$9,935
		Subtotal		**$1,003,482**
	Sales Tax (Based on)		9.8%	$98,341
		Subtotal		**$1,101,824**
	Bid Market Allowance		0.0%	$0
	TOTAL ESTIMATED CONSTRUCTION COST			**$1,101,824**
	Engineering, Legal & Administration Fees		15.0%	$165,274
	Owner's Reserve for Change Orders		5.0%	$55,091
	TOTAL ESTIMATED PROJECT COST			**$1,322,188**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

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DETAILED COST ESTIMATE

Project: Blower Replacement (Alternative 2)
Client: Las Virgenes Municipal Water District
Location: Calabasas, CA.
Element: 01 Mechanical

Date : November 9, 2011
By : Don DeMichele
Reviewed: 0

SPEC. NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL	TOTAL
	Division 02 - Site Construction					
02220	30" Metal Pipe, Rem From Bldg Or Process Area	60	LF	$75.36	$4,522	
	Total					**$4,522**
	Division 11 - Equipment					
11000	Single-Core Turbo Blower (350 hp Neuros NX350)	2	EA	$290,124.99	$580,250	
	Total					**$580,250**
	Division 15 - Mechanical					
15252	12" A-53 Welded Steel 3/8" (Std) Wall Pipe In A Bldg	60	LF	$154.19	$9,251	
15252	30" A-53 Wld Steel 3/8" (Std) Wall Pipe In A Bldg	60	LF	$367.04	$22,022	
	Total					**$31,273**
	Grand Total					**$616,045**

DETAILED COST ESTIMATE

Project: Blower Replacement (Alternative 2)
Client: Las Virgenes Municipal Water District
Location: Calabasas, CA.
Element: 02 Electrical

Date : November 9, 2011
By : Don DeMichele
Reviewed: 0

SPEC. NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL	TOTAL
	Division 16 - Electrical					
16000	#2/0 5kV-133% MV-105 Conductor	450	LF	$6.98	$3,143	
16000	#2/0 5kV-133% MV-105 Conductor Terminations	12	EA	$221.06	$2,653	
16000	300 kcmil Conductor	900	LF	$12.53	$11,280	
16000	300 kcmil Conductor Terminations	48	EA	$81.02	$3,889	
16000	#1/0 Conductor	300	LF	$5.80	$1,741	
16000	#1/0 Conductor Terminations	16	EA	$37.47	$600	
16000	U.G. Ductbank and Conduit	1	EA	$21,100.00	$21,100	
16000	Control Wiring to new MCP	1	EA	$10,000.00	$10,000	
16000	LCP's for Existing Blowers (HOA, Start/Stop)	3	EA	$2,000.00	$6,000	
16000	Filter/Step-down Transformer	2	EA	$45,000.00	$90,000	
16000	Master Control Panel	1	EA	$40,000.00	$40,000	
	Total					**$190,405**
	Grand Total					**$190,405**

Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Blower Replacement (Alternative 3)**	**Estimate Class:**	
Client:	**Las Virgenes Municipal Water District**	**PIC:**	
Location:	**Calabasas, CA.**	**PM:**	
Zip Code:	**91302**	**Date:**	**November 9, 2011**
Carollo Job #	**8578B.00**	**By:**	**Don DeMichele**
		Reviewed:	

NO.	DESCRIPTION			TOTAL
01	Mechanical			$455,682
02	Electrical			$167,925
				$0
				$0
				$0
				$0
				$0
				$0
				$0
		TOTAL DIRECT COST		**$623,607**
	Contingency		10.0%	$62,361
		Subtotal		**$685,967**
	General Contractor Overhead, Profit & Risk		12.0%	$82,316
		Subtotal		**$768,284**
	Escalation to Mid-Point		1.0%	$7,683
		Subtotal		**$775,966**
	Sales Tax (Based on)		9.8%	$76,045
		Subtotal		**$852,011**
	Bid Market Allowance		0.0%	$0
	TOTAL ESTIMATED CONSTRUCTION COST			**$852,011**
	Engineering, Legal & Administration Fees		15.0%	$127,802
	Owner's Reserve for Change Orders		5.0%	$42,601
	TOTAL ESTIMATED PROJECT COST			**$1,022,413**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

Printed: 10/28/2010

DETAILED COST ESTIMATE

Project: Blower Replacement (Alternative 3)
Client: Las Virgenes Municipal Water District
Location: Calabasas, CA.
Element: 01 Mechanical

Date : November 9, 2011
By : Don DeMichele
Reviewed: 0

SPEC. NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL	TOTAL
	Division 02 - Site Construction					
02220	30" Metal Pipe, Rem From Bldg Or Process Area	30	LF	$75.36	$2,261	
	Total					**$2,261**
	Division 11 - Equipment					
11000	Dual-Core Turbo Blower (700 hp Neuros NX700)	1	EA	$435,000.00	$435,000	
	Total					**$435,000**
	Division 15 - Mechanical					
15252	30" A-53 Wld Steel 3/8" (Std) Wall Pipe In A Bldg	30	LF	$367.04	$11,011	
15252	20"A-53 Wld Steel 3/8" (Std) Wall Pipe In A Bldg	30	LF	$247.00	$7,410	
	Total					**$18,421**
	Grand Total					**$455,682**

Form Rev: 2008June

Engineers...Working Wonders With Water®

DETAILED COST ESTIMATE

Project: Blower Replacement (Alternative 3)
Client: Las Virgenes Municipal Water District
Location: Calabasas, CA.
Element: 02 Electrical

Date : November 9, 2011
By : Don DeMichele
Reviewed: 0

SPEC. NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL	TOTAL
	Division 16 - Electrical					
16000	Master Control Panel	1	EA	$40,000.00	$40,000	
16000	#4/0 5kV-133% MV-105 Conductor	450	LF	$7.46	$3,356	
16000	#4/0 5kV-133% MV-105 Conductor Terminations	24	EA	$200.29	$4,807	
16000	300 kcmil Conductor	1200	LF	$12.53	$15,040	
16000	300 kcmil Conductor Terminations	48	EA	$81.02	$3,889	
16000	#3/0 Conductor	400	LF	$8.72	$3,490	
16000	#3/0 Conductor Terminations	16	EA	$53.93	$863	
16000	#4 Conductor	150	LF	$2.56	$385	
16000	#4 Conductor Terminations	4	EA	$23.70	$95	
16000	U.G. Ductbank and Conduit	1	EA	$10,000.00	$10,000	
16000	Control Wiring to new MCP	1	EA	$10,000.00	$10,000	
16000	LCP's for Existing Blowers (HOA, Start/Stop)	3	EA	$2,000.00	$6,000	
16000	Blower Filter/Step-down Tranformer	1	EA	$70,000.00	$70,000	
	Total					**$167,925**
	Grand Total					**$167,925**

Form Rev: 2008June

Appendix B

BLOWER REPLACEMENT LIFECYCLE COST DATA

Blower Replacement Alternative No. 1 - Lifecycle Cost Evaluation

Description -

Installation of two 350-hp single stage Siemens KA10 blowers at project year 0 (2012). Installation of third KA10 blower at project year 10 (2022) followed by decommissioning of existing Hoffman blowers.

Calendar Year	2012	2017	2022	2027	2032	
Project Year	0	5	10	15	20	
Average Plant Air Flows (SCFM)	7,380	7,720	8,050	8,410	9,050	
Peak Plant Air Flows - Normal Operation (SCFM)	12,270	12,960	13,650	14,410	15,750	
Peak Plant Air Flows - Reliability Mode (SCFM)	18,155	19,370	20,555	21,830	24,100	
Capacity w/Largest Blower Out of Service (SCFM)	15,950	15,950	16,300	16,300	16,300	
Total Plant Air System Capacity (SCFM)	24,100	24,100	24,450	24,450	24,450	
Costs						NPW ($)[1]
Capital Costs ($)[2]						
Blower and Mechanical	$ 1,107,259	$ -	$ 724,978	$ -	$ -	$ 1,512,083
Electrical and Control	$ 207,875	$ -	$ 70,849	$ -	$ -	$ 247,437
Annual Operating Costs ($/Yr.)						
Energy[3]	$ 160,897	$ 194,872	$ 235,409	$ 289,645	$ 360,490	$ 2,761,820
Maintenance	$ 3,000	$ 3,432	$ 3,927	$ 5,392	$ 6,169	$ 48,961
Parts Replacement[4]	$ -	$ 2,228	$ 2,481	$ 4,145	$ 4,616	$ 7,198
					Total NPW ($)	$ 4,577,499

Notes:

(1) Net present worth based on 6% discount rate.

(2) Capital costs include blower installation.

(3) Energy costs are based on a 3% annual escalation rate.

(4) Replacement of bearings every four years at a cost of $1,000 per KA10 blower (year 2012 currency).

Blower Replacement Alternative No. 2 - Lifecycle Cost Evaluation

Description -

Installation of two 350-hp Neuros Turbo blowers at project year 0 (2012). Installation of one additional 350-hp Turbo blower at project year 10 (2022), followed by decomissioning of existing Hoffman blowers.

Calendar Year	2012	2017	2022	2027	2032	
Project Year	0	5	10	15	20	
Average Plant Air Flows (SCFM)	7,380	7,720	8,050	8,410	9,050	
Peak Plant Air Flows - Normal Operation (SCFM)	12,270	12,960	13,650	14,410	15,750	
Peak Plant Air Flows - Reliability Mode (SCFM)	18,155	19,370	20,555	21,830	24,100	
Capacity w/Largest Blower Out of Service (SCFM)	15,950	15,950	15,172	15,172	15,172	
Total Plant Air System Capacity (SCFM)	23,536	23,536	22,758	22,758	22,758	
Costs						NPW ($)[1]
Capital Costs ($)[2]						
Blowers and Mechanical	$ 1,010,006	$ -	$ 661,301	$ -	$ -	$ 1,379,273
Electrical and Control	$ 312,169	$ -	$ 128,815	$ -	$ -	$ 384,099
Annual Operating Costs ($/Yr.)						
Energy[3]	$ 171,446	$ 205,791	$ 247,470	$ 297,980	$ 367,871	$ 2,868,273
Maintenance	$ 2,000	$ 2,288	$ 2,618	$ 3,145	$ 3,599	$ 30,280
Parts Replacement[4]	$ -	$ -	$ 104,728	$ -	$ -	$ 58,480
					Total NPW ($)	$ 4,720,404

Notes:

(1) Net present worth based on 6% discount rate.

(2) Capital costs include blower installation.

(3) Energy costs are based on a 3% annual escalation rate.

(4) Replacement of two 350-hp VFDs at project year ten at $40,000 per VFD (year 2012 currency).

Blower Replacement Alternative No. 3 - Lifecycle Cost Evaluation

Description -

Installation of one 700-hp Neuros Turbo blower at project year 0 (2012). Installation of one additional 700-hp Turbo blower at project year 10 (2022), followed by decomissioning of existing Hoffman blowers.

Calendar Year	2012	2017	2022	2027	2032	
Project Year	0	5	10	15	20	
Average Plant Air Flows (SCFM)	7,380	7,720	8,050	8,410	9,050	
Peak Plant Air Flows - Normal Operation (SCFM)	12,270	12,960	13,650	14,410	15,750	
Peak Plant Air Flows - Reliability Mode (SCFM)	18,155	19,370	20,555	21,830	24,100	
Capacity w/Largest Blower Out of Service (SCFM)	15,308	15,308	22,524	22,524	22,524	
Total Plant Air System Capacity (SCFM)	22,816	22,816	30,032	30,032	30,032	
Costs						NPW ($)[1]
Capital Costs ($)[2]						
Blowers	$ 747,091	$ -	$ 978,315	$ -	$ -	$ 1,293,376
Electrical and Control	$ 275,313	$ -	$ 203,958	$ -	$ -	$ 389,202
Annual Operating Costs ($/Yr.)						
Energy[3]	$ 172,397	$ 206,978	$ 248,897	$ 299,611	$ 370,059	$ 2,884,865
Maintenance	$ 1,300	$ 1,487	$ 1,702	$ 2,097	$ 2,399	$ 19,958
Parts Replacement[4]	$ -	$ -	$ 104,728	$ -	$ -	$ 58,480
					Total NPW ($)	$ 4,645,880

Notes:

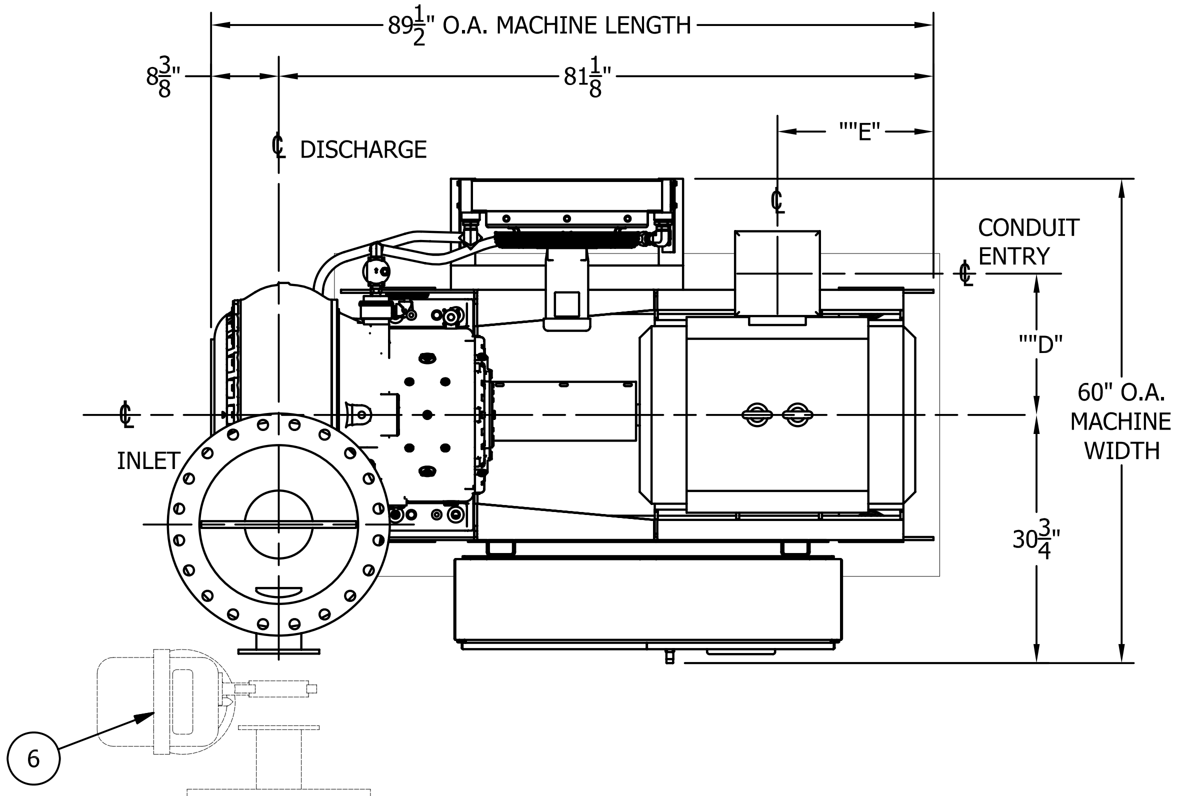
(1) Net present worth based on 6% discount rate.

(2) Capital costs include blower installation.

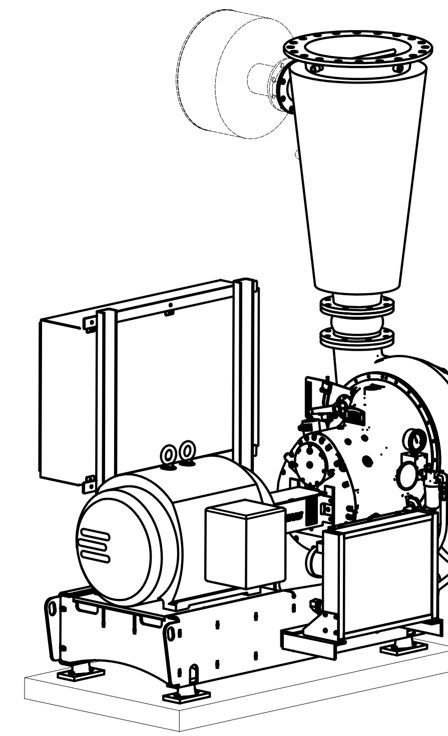
(3) Energy costs are based on a 3% annual escalation rate.

(4) Replacement of two 350-hp VFDs at project year ten at $40,000 per VFD (year 2012 currency).

BLOWER MECHANICAL DRAWINGS



PLAN VIEW



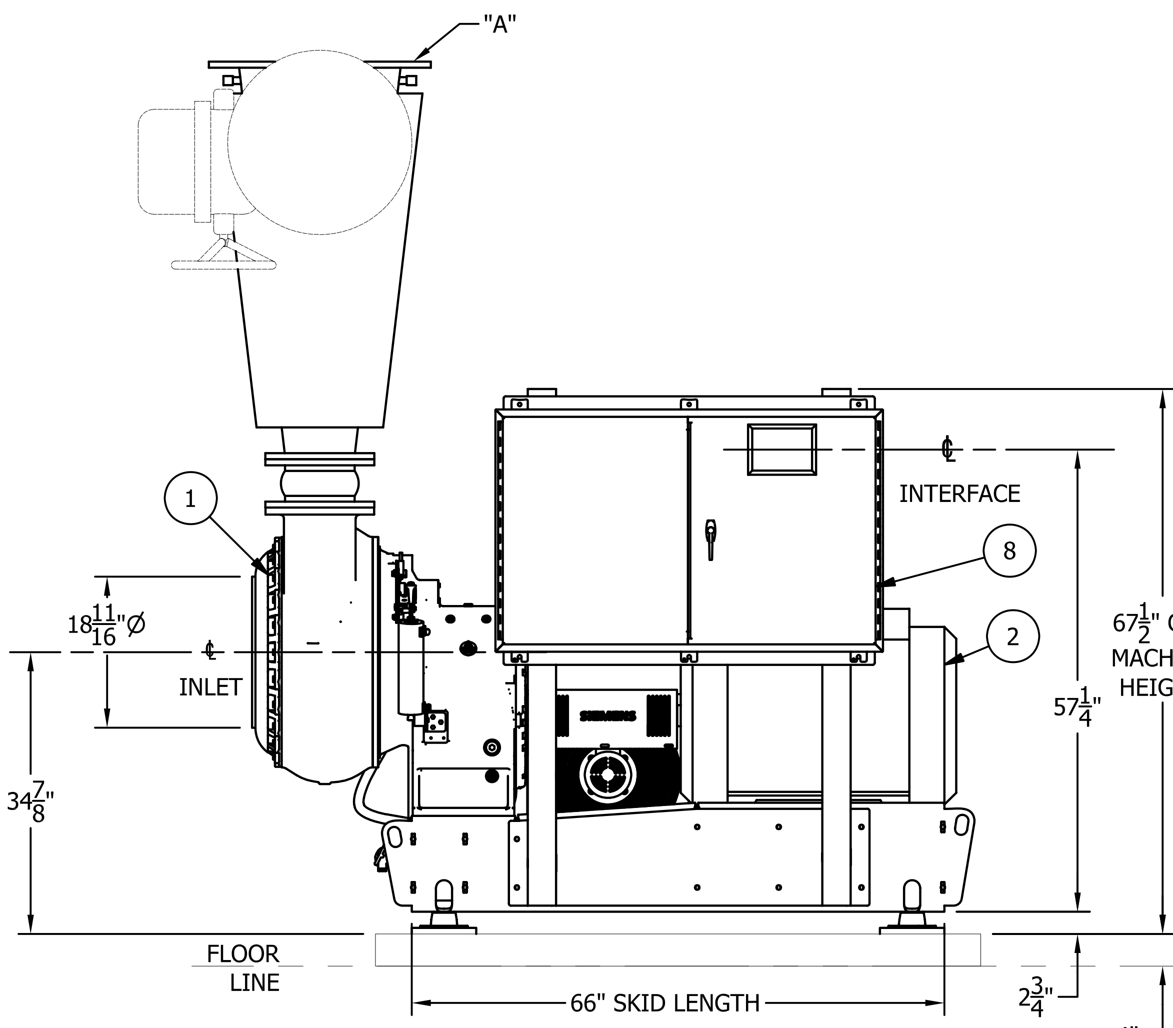
ISOMETRIC VIEW

ITEM	DESCRIPTION	LBS.
1	COMPRESSOR	2205
2	MOTOR (SEE TABLE)	1750
3	VIBRATION ISOLATOR	36
4	DISCHARGE CONE/SILENCER (SEE TABLE) (SHIP LOOSE)	
5	DISCHARGE EXPANSION JOINT (SHIP LOOSE)	18
6	BLOW-OFF VALVE (SHIP LOOSE)	84
7	BLOW-OFF SILENCER, 5" (SHIP LOOSE)	149
8	LOCAL CONTROL PANEL	275
9	COOLER OIL/AIR	61

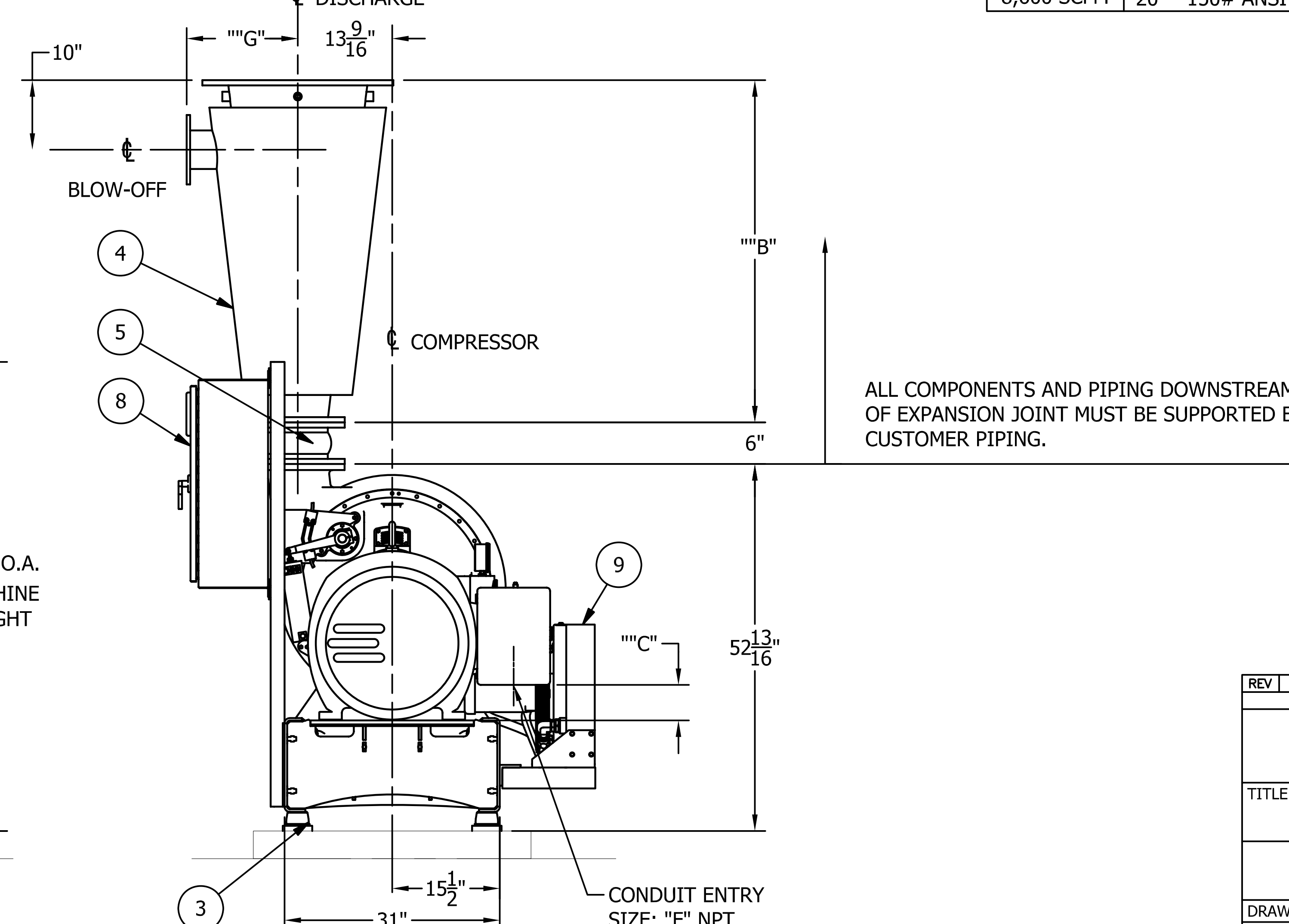
ESTIMATED COMPRESSOR PACKAGE WEIGHT: ------------- 4,827 lbs.

MOTOR TABLE						
HP	FRAME	C	D	E	F (NPT)	WEIGHT
250-300 HP	445TS	4"	17 3/8"	17 3/8"	3"	1,750
400-450 HP	447TS	4"	17 1/2"	15 5/8"	4"	1,750

DISCHARGE CONE/SILENCER TABLE				
MAX. FLOW	A - FLANGE	B - CONE LENG	G	WEIGHT
5,500 SCFM	16" - 150# ANSI	32 7/8"	14"	227
8,600 SCFM	20" - 150# ANSI	49 1/4"	16"	341



ELEVATION VIEW



REAR ELEVATION

ALL COMPONENTS AND PIPING DOWNSTREAM OF EXPANSION JOINT MUST BE SUPPORTED BY CUSTOMER PIPING.

REV	DATE	BY	DESCRIPTION
REVISION HISTORY			

SIEMENS
TURBOMACHINERY SOLUTIONS

TITLE: GENERAL ARRANGEMENT DRAWING FOR MODEL STC-GO KA10S-GK200

STANDARD

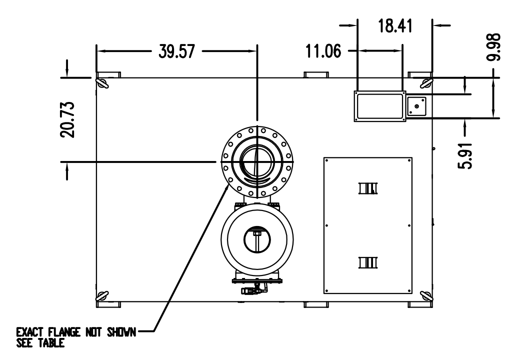
DRAWN BY: DSH	CHECKED BY:
DATE: 07/16/10	APPROVED BY:
SCALE: N.T.S.	
PATH:	

REV.

DRAWING NUMBER GA01B67

Drawing same for NX300 and NX350

SYM	DESCRIPTION	Q'TY	
1	BLOWER ENCLOSURE	1	PX4331-SR-SPL07061801 (KCC)
2	BLOW-OFF VALVE	1	PE200 DARK GRAY 4G6-7.9B 4.3/0.6 (Chokwang-Paint)
3	BLOW-OFF SILENCER	1	PX4331-SR-SPL07061801 (KCC)
4	CONTROLLER	1	EX8816 BLUE (KCC)
5	DISCHARGE CONE	1	PX4331-SR-SPL07061801 (KCC)
6	NOISE SUPPRESSION COVER	1	
7	RADIATOR	1	
8	WATER PUMP	1	
9	WATER TANK	1	50 LITER, SST304
10	COOLING AIR INLET AND INLET INVERTER FILTER	1	
11	REACTOR	1	
12	INVERTER	1	
13	INLET AIR FILTER	1	

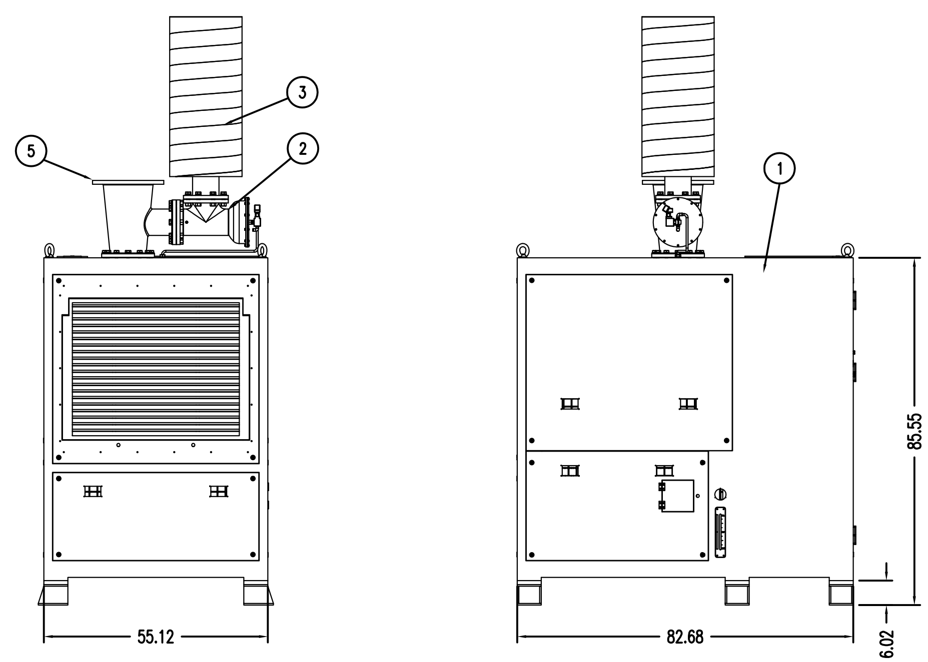


TOP VIEW

LENGTH 'L': INCLUDING 1/8" THK. GASKET

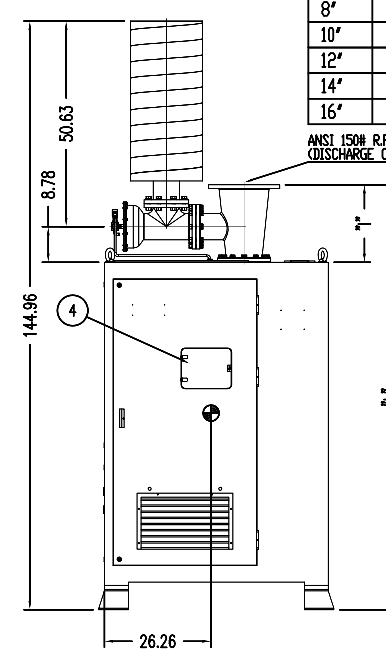
OUTLET AIR CONE EXIT SIZE			
SIZE	LENGTH 'l'	LENGTH 'L'	'L' TOL. +/-
8"	18.98"	104.65"	0.25"
10"	18.98"	104.65"	0.25"
12"	18.98"	104.65"	0.25"
14"	25.43"	111.11"	0.25"
16"	39.96"	125.64"	0.25"

ANSI 150# R.F. FLANGE (SEE TABLE)
(DISCHARGE CONE CONNECTION)

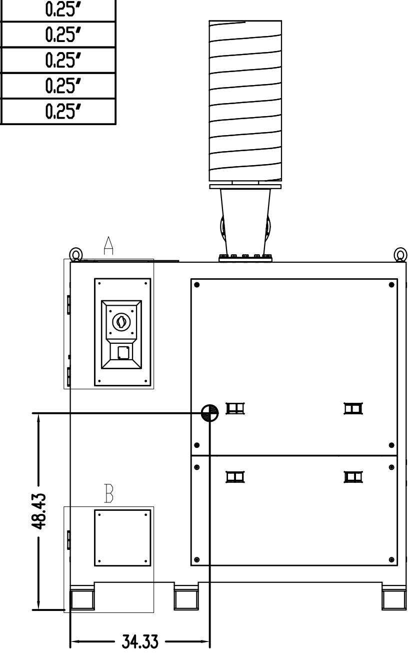


REAR VIEW

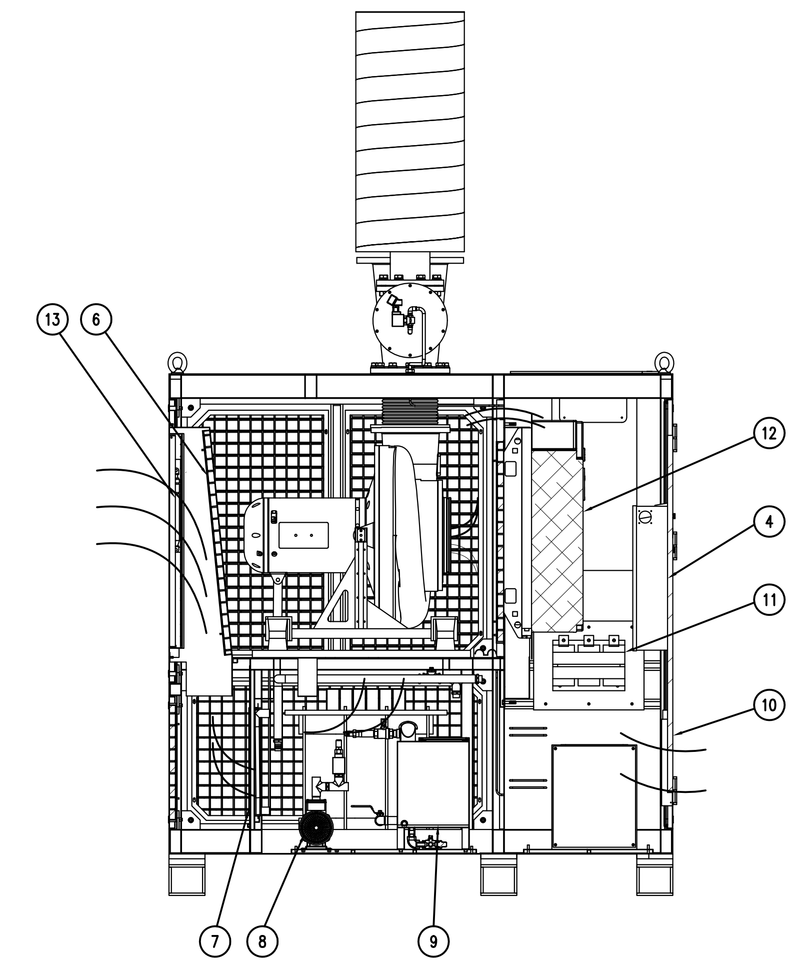
LEFT VIEW



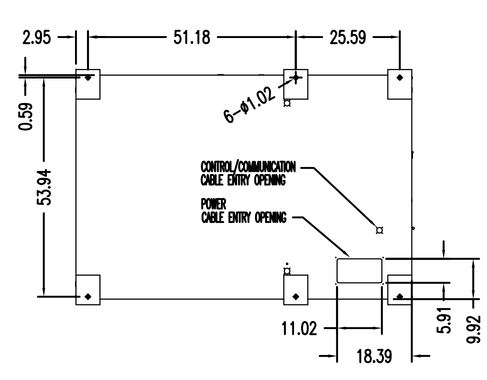
FRONT VIEW



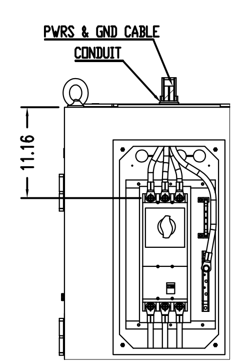
RIGHT VIEW



CUTAWAY VIEW

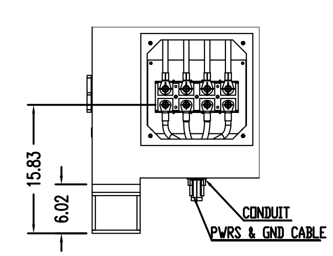


BOTTOM VIEW



DETAIL A

(COVER OMITTEM FOR CLARITY)



DETAIL B

(COVER OMITTEM FOR CLARITY)

UNLESS OTHERWISE NOTED:

1. ALL DIMENSIONS ARE IN [INCHES].

2. THIRD ANGLE PROJECTION:

DATE	PAR BY	VER. CHEC.	APP.	DESCRIPTION	REV.
SEPT/16/2010	D.P.			ISSUED FOR INFORMATION	A

APG-NEUROS
3200 Cours Le Corbusier, Boisbriand, Quebec J7G 3E8
Tel: 450 939-0799 Toll free: 1 866 592-9482
Fax: 450 939-2115 www.APG-Neuros.com

FOR / POUR

TITLE / TITRE: NX-300 - STD LOUVERED INLET - ANCHOR FOOT 8" TO 16" ANSI R.F. FLANGED OUTLET

PROJECT No.:

DRAWING No. / No. DE DESSIN: D-0300-SI0003

MSTR No.: NEUROS SEPT2010

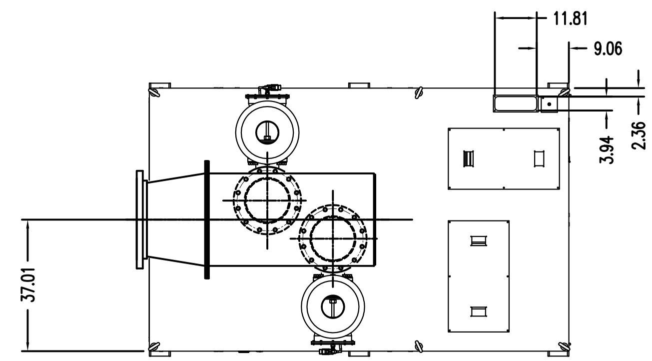
SC. / ECH.: 1/2" = 1'-0"

SHEET / PAGE: 1 OF 1

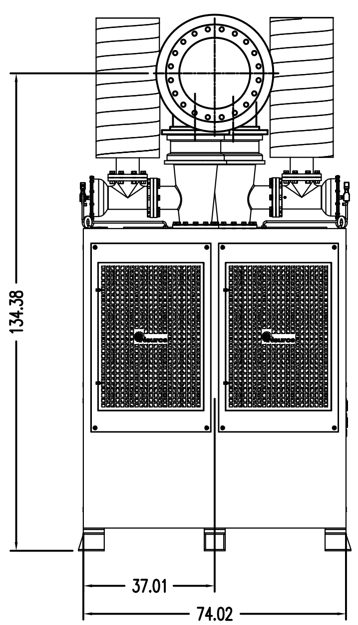
REV: A

Drawings same for NX600 and NX700

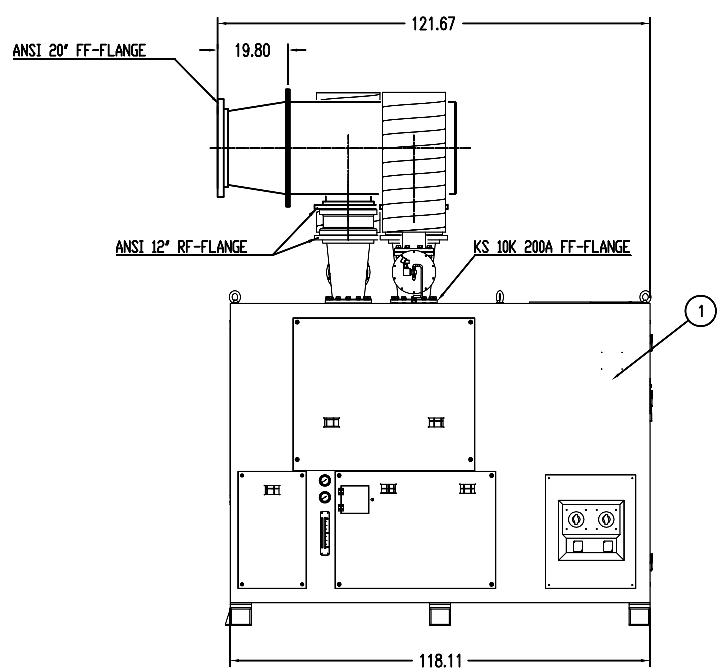
SYM	DESCRIPTION	Q'TY	REMARK
1	BLOWER ENCLOSURE	1	FRZ089 / PE100 TX (Chokwang-Paint)
2	BLOW-OFF VALVE	2	FEM395 / EP200 DARK GRAY (Chokwang-Paint)
3	BLOW-OFF SILENCER	2	FRZ089 / PE100 TX (Chokwang-Paint)
4	CONTROLLER	1	EX8816 BLUE KW (KCC) PLC + TOUCH SCREEN
5	DISCHARGE CONE	2	FRZ089 / PE100 TX (Chokwang-Paint)
6	NOISE SUPPRESSION COVER	2	
7	RADIATOR	2	
8	WATER PUMP	2	
9	WATER TANK	1	50 LITER , STS304
10	COOLING AIR INLET LOUVER & INLET INVERTER FILTER	1	
11	INPUT REACTOR	2	
12	INVERTER	2	
13	SINUS FILTER	2	



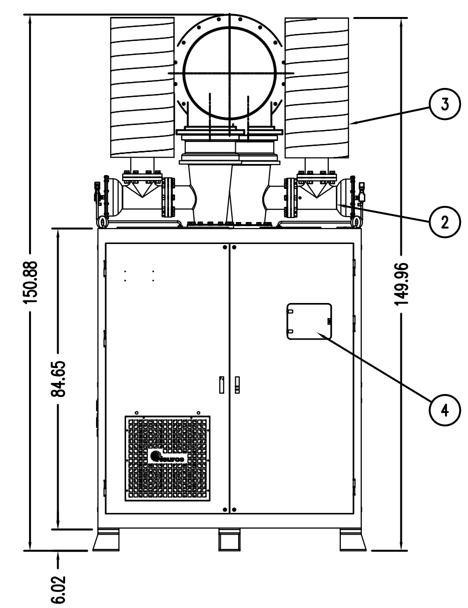
TOP VIEW



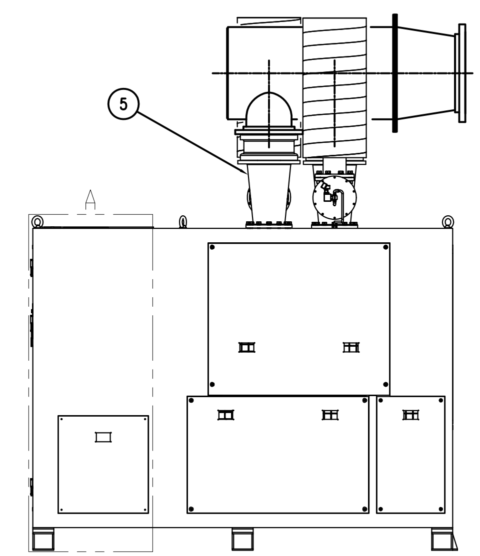
REAR VIEW



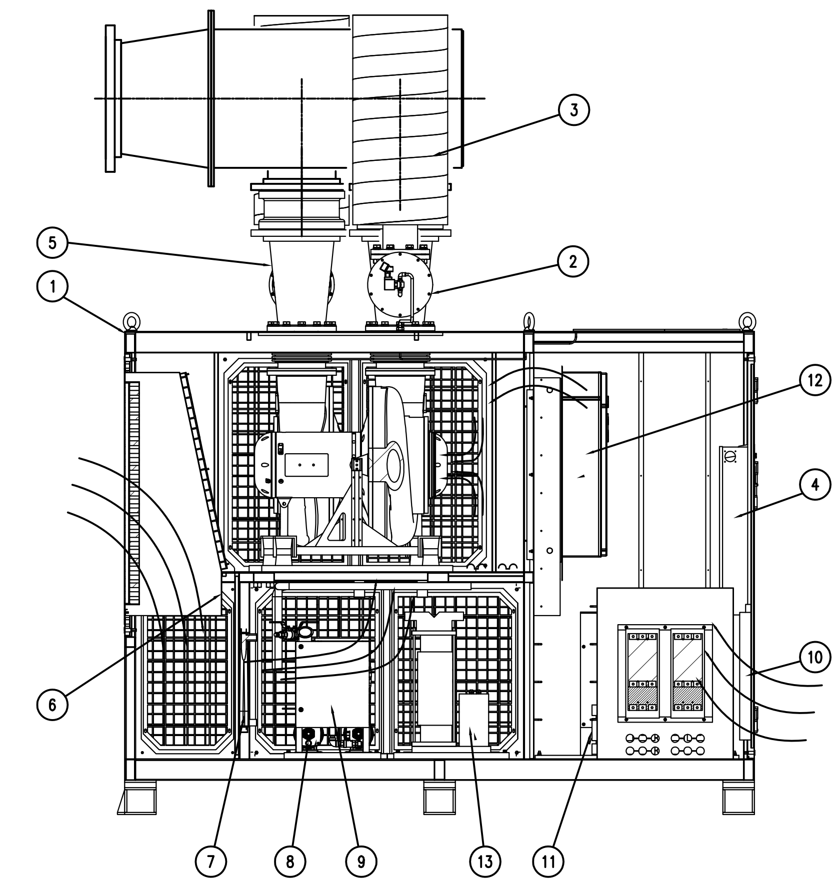
LEFT VIEW



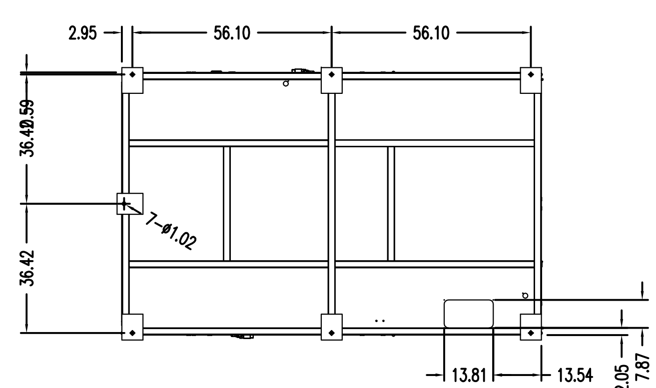
FRONT VIEW



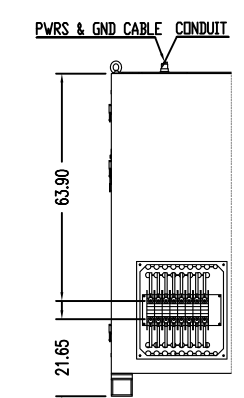
RIGHT VIEW



CUTAWAY VIEW



BOTTOM VIEW



DETAIL A

(COVER OMITTEM FOR CLARITY)

UNLESS OTHERWISE NOTED:

1. ALL DIMENSIONS ARE IN [INCHES].

2. THIRD ANGLE PROJECTION:

DATE	PAR BY	VER. CHEC.	APP.	DESCRIPTION	REV.
SEPT/15/2010	D.P.			ISSUED FOR INFORMATION	A

APG-NEUROS
3200 Cours Le Corbusier, Boisbriand, Quebec J7G 3E8
Tel.: 450 939-0799 Toll free: 1 866 592-9482
Fax: 450 939-2115 www.APG-Neuros.com

FOR / POUR

TITLE / TITRE: NX-600 - STD LOUVERED INLET - ANCHOR FOOT
20" OUTLET 150# F.F. FLANGE

PROJECT NO.

DRAWING NO. / No. DE DESSIN: 0600-SI0003

MSTR NO.: NEUROS SEPT2010

SC. / ECH.: 7/16" = 1'-0"

SHEET / PAGE: 1 OF 1

REV: A