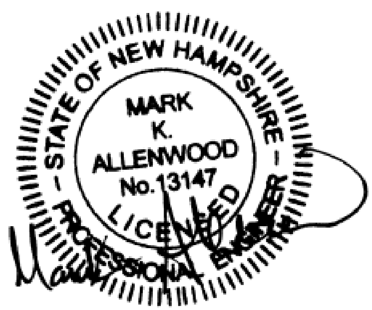
Digester Feasibility Study

Prepared for
City of Portsmouth, New Hampshire

Project No. 152936



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Executive Summary

Brown and Caldwell (BC) was retained by the City of Portsmouth (City) to determine the economic viability of installing an anaerobic digestion facility to manage the solids generated from their wastewater treatment process as well as regional sources of organic feedstocks. The City operates two wastewater treatment facilities (WWTFs), Pease WWTF and Peirce Island WWTF. The Pease WWTF treats wastewater collected from within the Pease Development Authority and Peirce Island WWTF treats wastewater collected from the City, portions of Rye and Greenland, and all of New Castle. Through a series of technical memoranda (TMs), BC has outlined the necessary programmatic and design elements associated with implementing a digestion facility (for both indigenous solids and regional configurations) and the net economic outlook. This executive summary (ES) will present the highlights from each TM.

TM1: Flows and Loads Evaluation

Pease WWTF has capacity to treat 1.2 million gallons per day (mgd). It is a secondary treatment facility with primary settling, sequencing batch reactors, and chlorine disinfection prior to discharge into the Piscataqua River. The solids are dewatered in a belt filter press (BFP) then hauled for disposal. Figure ES-1 provides a detailed process flow diagram of the treatment process.

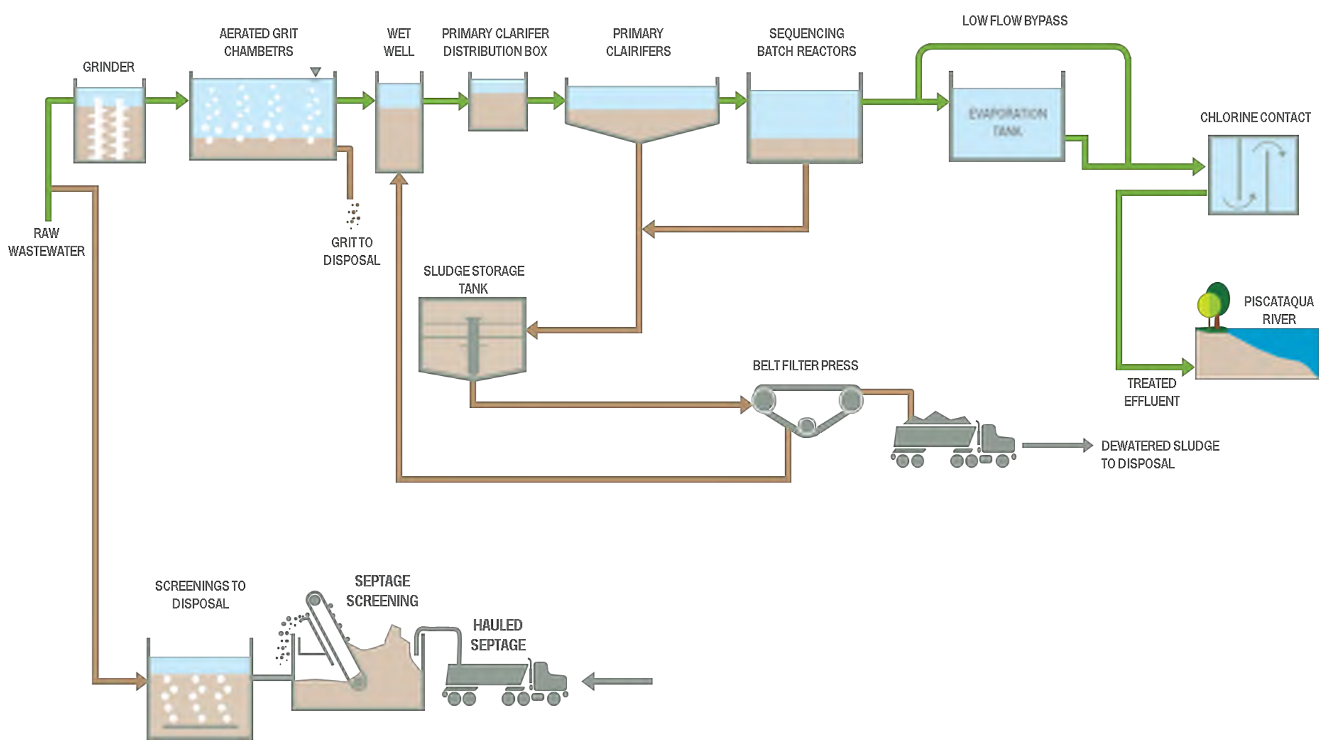

Figure ES-1. General process flow diagram of Pease WWTF

Constructed in the mid-1960s as a primary treatment facility, the Peirce Island WWTF has a current treatment capacity of 4.8 mgd with a peak flow of 22 mgd during wet weather. The Peirce WWTF is undergoing a major construction upgrade to an average day treatment capacity of 6.1 mgd that will include new preliminary treatment, new secondary treatment and new biosolids handling systems. Shown in Figure ES-2, the treatment process upgrades consist of raw wastewater screening, aerated grit chambers and chemically enhanced primary treatment (CEPT). Wastewater solids are gravity thickened prior to screw press dewatering and loadout.

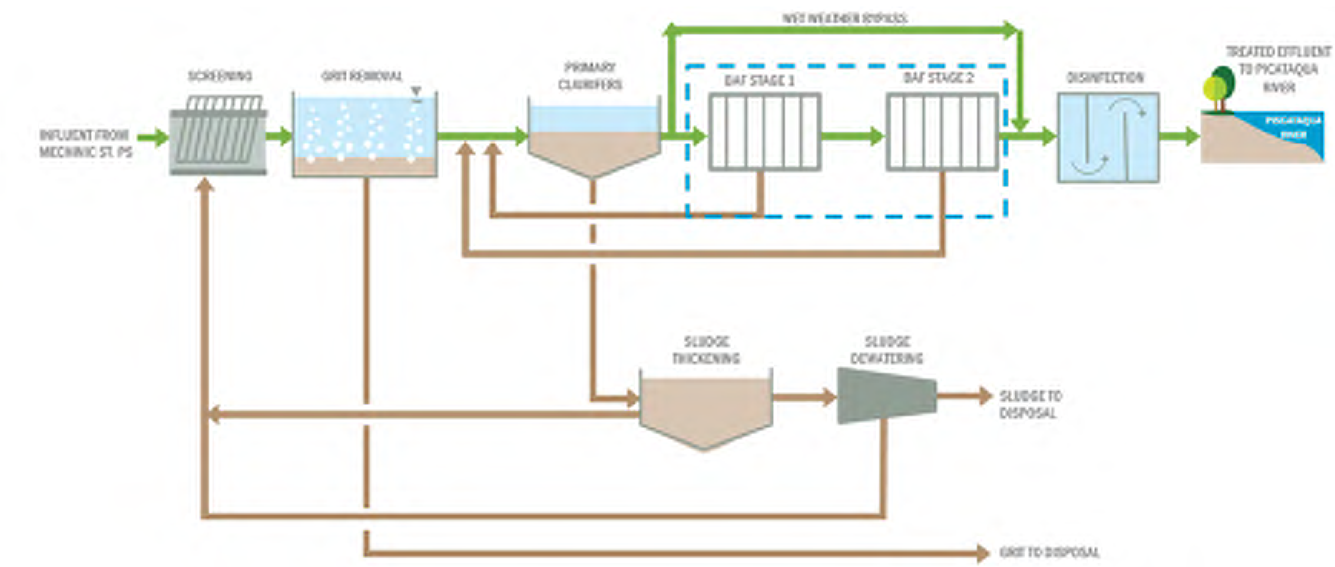

Figure ES-2. General process flow diagram of Peirce Island WWTF

In 2010, the City performed a Waste Management Plan (WMP) identifying several WWTFs in the region as potential sources for imported WWTF solids for a regional biosolids processing facility (RBPF), as well as sources of fats, oils, and grease (FOG) for co-digestion. In addition, the City is considering a residential source separated organic (RSSO) program to recover the organic fraction of municipal solid waste for co-digestion and diversion from the landfill. Table ES-1 summarizes the anticipated solids loading for indigenous solids, imported solids, FOG, and RSSO used in these analyses.

Table ES-1. Summary of Solids Loading to the RSPF

	2020		2040	
	TS – lbs/day	VS – lbs/day	TS – lbs/day	VS – lbs/day
Pease WWTF	1,200	970	1,500	1,200
Peirce Island WWTF	7,700	6,100	15,900	12,300
Regional Sludges	30,100	24,100	42,500	34,000
Fats, Oils and Grease	620	560	620	560
Source Separated Organics	1,500	1,200	1,500	1,200
Total	41,100	32,930	62,000	49,200

TM2: Conceptual Digestion Facilities Sizing and Configuration

Representative digestion technologies were selected to develop a conceptual design for cost estimating purposes in TM2. It was assumed that the digestion facility would be sited at Pease WWTF and receive dewatered cake for digestion. The most widely accepted method of pretreating dewatered cake upstream of digestion is the thermal hydrolysis process (THP) and as such it was selected for use with conventional mesophilic anaerobic digestion (MAD). This TM presents the basic sizing criteria and qualitative process considerations for THP and MAD, as well as the associated major sub-systems and ancillary processes. The technologies considered for the digestion facility and the general process flow is depicted below in Figure ES-3.

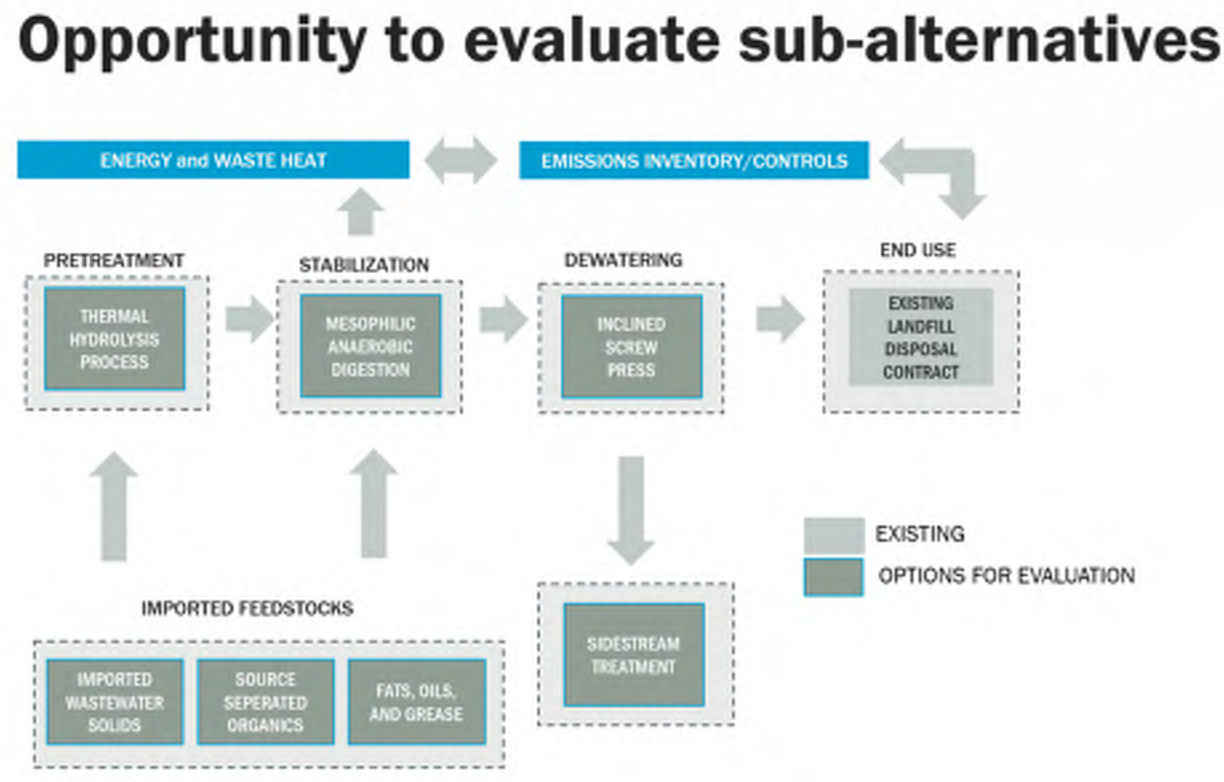

Figure ES-3. Unit processes considered for the RBPF

Concurrent with evaluating the technical viability of the digestion facility, a conceptual design layout was developed to determine if the Pease WWTF site could accommodate the infrastructure and identify potential logistics surrounding facility construction. Using a combination of City input, BC experience, and process analysis results, a conceptual facility layout was developed and is illustrated below in Figure ES-4. This study evaluated the land available near the Pease WWTF and did not consider implementation of an offsite facility given the additional complexity and cost associated with identifying and purchasing the land. Any future evaluation for an offsite digestion facility would have to factor in the additional cost to acquire the property for the facility and obtain the necessary permits.

The new digestion facilities are shown in areas identified as wetlands by the City. Construction in these areas may require additional measures, such as wetland offset trading as well as City, State and Federal approvals. Other considerations for the site include planning and zoning reviews, local building permits, permitting for construction practices, and approval from the Pease Development Authority. Additional site review requirements such as historical resource review and endangered species review may also apply.

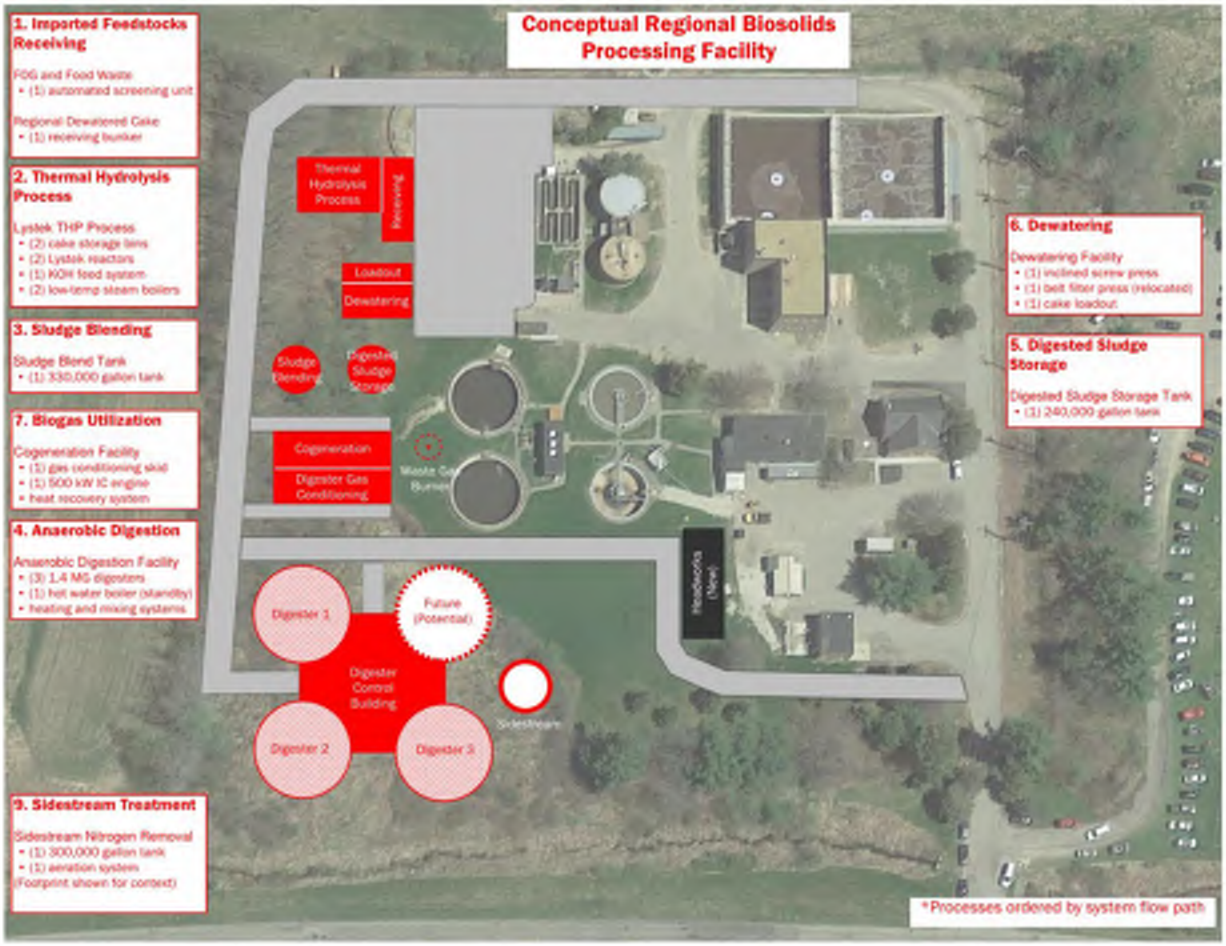

Figure ES-4. RBPF Layout at the Pease WWTF site

TM 3: Energy Systems Evaluation

A core component of digestion facilities is recovery and utilization of the energy-rich digester gas. This TM describes the Energy Systems Evaluation conducted for digester gas utilization in a combined heat and power (CHP) energy recovery system. The Energy Systems Evaluation was conducted in the context of satisfying the following project drivers. A CHP system was selected due to the its ability to offset electricity costs, which provides a more reasonably certain estimate of revenue projections compared to options like upgrading to vehicle fuel that are more dependent on the value of federal incentive programs.

The evaluation is based on two alternatives: Alternative 1 that considers digestion of the municipal wastewater solids from Peirce Island and Pease WWTFs only, and Alternative 2 that assumes co-digestion of solids from Peirce Island and Pease WWTFs with imported materials, including outside cake, FOG, and RSSO. The basis of evaluation for the two solids loading alternatives in this evaluation is presented in Table ES-2.

Table ES-2. Digester Gas Production Estimates: Two Alternatives			
Alternative	2020 Average Gas Production, scfm	2040 Average Gas Production, scfm	Comments
1. Peirce and Pease WW Solids	38	85	Only WW municipal solids; no import
2. Peirce and Pease WW Solids + Import	193	297	Assumes outside cake, THP, and FOG imported for co-digestion

Preliminary Engine Sizing

To determine preliminary engine sizes, the total available digester gas energy was converted to an electrical power output assuming an engine electrical efficiency of 36 percent. Based on the estimated electrical power output, engine sizes were selected with the following considerations in mind:

- Engine would be partially loaded at average conditions to provide capacity for high-production conditions and accommodate future digester gas production (see Table ES-3);
- Multiple suppliers are available to provide selected engine size to allow for competitive bidding;
- Allow for one engine to utilize digester gas available anticipated at startup;
- Select engine to produce power up to new RBPF demand; assume excess digester gas is flared and additional power is not exported.

Table ES-3. Proposed Engine Fuel Consumption				
Alternative	Proposed Engine Size (kW)	Output to RBPF Demand (kW)	Percent of Digester Gas Utilized (percent)	Load Operation (percent)
Alt 1 – CHP	1 at 335 kW	395	61	88
Alt 2 – CHP	1 at 788 kW	693	61	88

Electrical Interconnection

The cogeneration system must be electrically interconnected to the electrical distribution system, in parallel and synchronized with the local electrical grid, per the utility's (Eversource) interconnection standard. At this stage in the evaluation, it has been assumed that the cogeneration system will be sized to meet the on-site power demands and will not include net electrical metering (NEM) for export. If the project is advanced, a business case evaluation for using net metering to offset City electrical costs at Peirce Island WWTF or City pump stations should be considered.

TM4: Financial Model Evaluation

The following two alternatives were considered for analysis and comparison to the planning baseline (status quo).

- Planning Baseline: Status quo operation
- Alternative 1: THP with MAD and CHP for Pease and Peirce Island WWTFs solids only
- Alternative 2: THP with MAD and CHP for Pease and Peirce Island WWTFs solids and imported wastewater solids and HSOW (FOG and RSSO) co-digestion

As a conservative measure, no funding or grants are included in the NPV analysis (Table ES-4). Electricity production renewable portfolio standards (RPS) credits are, however, included in the NPV analysis because they are not competitive to obtain.

Table ES-4. Estimated NPV for Feasibility Study Alternatives [a]

Cost Component	Planning Baseline (Status Quo)	Thermal hydrolysis with Mesophilic Anaerobic Digestion with IC Engine CHP System	
		Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
Total Capital Costs	$0	$40,480,000	$84,480,000
20-Year Projected Revenue	$0	-$4,700,000	-$57,000,000
20-Year Projected Total O&M Costs	$35,700,000	$30,100,000	$63,700,000
20-year NPV (Lifecycle Cost)	$35,700,000	$65,880,000	$91,180,000

a. *These numbers are based upon the various assumptions and variables indicated in the report, including a Class 5 cost estimate. Changes to key variables or assumptions may impact these results in a favorable or unfavorable manner. A more detailed project vetting should be undertaken as a next step to further refine this analysis.*

Based on the financial parameters assumed as part of this base evaluation, installing digesters is not financially advantageous under either alternative scenario. Addition of digesters does reduce the annual operational and maintenance costs and generate revenue, however the significant capital outlay required results in a simple payback of 80 years for Alternative 1 and 60 years for Alternative 2.

As part of the economic evaluation, potential changes in cost parameters that could occur in the future were assessed to identify trigger points that would change the economics of the project going forward (Table ES-5). Specifically, the cost factors listed in Table ES-4 were identified as having an impact on the overall economic viability of digester facility either positively or negatively in the future.

Table ES-5. Economic Evaluation Trigger Points

Potential to Improve Digester Economics	Potential to Worsen Digester Economics
Digested Solids Disposal Rate: This project assumes the digested solids are still disposed of at the same landfill that the existing solids currently are hauled too. If beneficial uses for the digested solids are identified the disposal cost of the digested solids could be reduced. For example, if the digested solids disposal cost is half the current rate ($35/ton compared to $70/ton) the additional 20-year projected cost savings is: • $4.6M (Alternative 1) • $16.6M (Alternative 2)	**Project Siting:** As discussed in TM3, this project was conceptually sited at the Pease WWTF in existing wetlands. Constructing on wetlands adds additional unknowns in capital cost estimating given permitting and structural design considerations. Additionally, if the project had to be located offsite, additional capital would be required to purchase the land.

Table ES-5. Economic Evaluation Trigger Points	
Potential to Improve Digester Economics	Potential to Worsen Digester Economics
Upgrading to Vehicle Fuel with Stable Incentives: Substantial economic opportunities exist with upgrading digester gas to renewable natural gas quality and selling it as vehicle fuel under the federal Renewable Portfolio Standard. However, the value of these incentives are currently deflated due to the EPA's current targets for the program. If these targets (and incentive values) are returned to values seen under the previous administration, the opportunity for gross revenue generation with vehicle fuel is 2 to 3 times realized from offsetting electricity costs.	**Air Permitting:** This project assumes basic post-combustion treatment of CHP exhaust. However, more stringent air permitting requirements may be implemented in the future, increasing the lifecycle cost of CHP systems and administrative time required to comply with the air permitting requirements.
Imported Feedstocks Tipping Fees: Current wastewater solids disposal rates are increasing in the Northeast. Additionally, diversion of SSO from landfills is being further promoted in the region. This could lead to the ability to charge a higher tipping fee for imported feedstocks. For example, charging $100/ton for receipt of wastewater solids and $0.10/gallon for SSO and FOG improves the 20-year project cost savings of Alternative 2 by $29.8M.	**Contaminants of Emerging Concern:** Current concern exists over the presence of anthropogenic chemicals found in wastewater solids. If wastewater solids disposal options become further limited due to these concerns in the future, digestion represents a major capital investment that results in a relatively low ability to reduce solids mass and minimize disposal risk compared to thermal technologies like drying and incineration or emerging processes like pyrolysis.

TM 5: Procurement and Planning

The delivery method for installing a biosolids processing facility would have to be determined if the project were to be advanced. TM 5 provides an overview of various procurement and delivery methods that can be used to implement a biosolids processing facility construction program.

TM 6: Preliminary Sludge Dryer Evaluation

Although the core focus of this study was to evaluate the economic feasibility of digestion, consideration was also given to assessing the viability of a wastewater solids dryer as part of an overall wastewater solids management strategy. This TM presents conceptual level costs associated with installing and operating a wastewater solids dryer for the alternatives considered in this study.

An overview of the initial cost evaluation data is summarized below in Table ES-6 along with the resulting range of simple payback projections. The net annual benefit column in Table ES-6 represent the savings achieved by reducing the annual disposal costs accounting for the burden of the additional O&M costs. A range of values is presented to represent different dryer installation scenarios, as well as the potential to lower disposal costs through production of a Class A dried product.

Table ES-6. Economic Viability Assessment Overview					
	Near Term Construction Costs	Annual Disposal Savings	Annual Dryer O&M Costs	Net Annual Benefit [a]	Simple Payback
Dryer for City Only Digesters	$6.3M - $8.9M	$0.30M - $0.70M	$0.59M - $0.61M	($0.31M) - $0.09M	None – 70 yrs
Dryer with No Digesters	$10.8M (only belt)	$0.62M - $1.38M	$0.82M (only belt)	($0.20M) - $0.56M	None – 19 yrs
Dryer for RBPF	$11.0M - $23.7M	$1.02M - $2.48M	$1.19M - $1.30M	($0.28M) to $1.29M	None - 9 yrs

Notes: a. difference between two previous columns

Table ES-7 shows that the dryer projects are largely impacted by economy of scale. Implementation of a dryer incurs some fixed capital outlay and O&M activities that are dampened with the larger value of potential savings at the larger scale alternatives. However, changing disposal costs and optimizations of the system would impact the simple payback projections. A trigger point analysis was conducted on the cost factors for a dryer project as well as presented below in table ES-7.

Table ES-7. Economic Viability Assessment Overview			
	Raw cake disposal increases to $160/ton Dried product can be disposed of at $40/ton	Can Utilize Existing Staff (Only 1 FTE added)	Utilizes Digester Gas
	Reduced Simple Payback		
Dryer for City Only Digesters	19	23	21
Dryer with No Digesters	10	14	11
Dryer for RBPF	5	8	6

Although the range of solids hauling and disposal and disposition costs evaluated in this trigger evaluation are theoretical at the time of this report, recent experience in the New England wastewater solids market supports the likelihood of these rates coming to bear in the near future. Wastewater solids management costs have been rising for years given the steady closure of landfills and wastewater solids incinerators, as well as public objection to odors and contaminants of emerging concern. Wastewater solids drying in this market also provides a greater level of cost control, by shifting the O&M costs from the wastewater solids management market to more readily known commodities such as natural gas and labor. In addition to operational cost savings, wastewater solids drying also provides a benefit in risk management, specifically long-term cost control, and the associated environmental benefit of producing a dried product with greater potential for beneficial reuse. As part of the due diligence necessary in the progression from initial economic viability assessment (this study) to design, the City would best be served by further developing these dryer alternatives and refining the core assumptions to verify the economic viability, as well as to identify opportunities for further system optimization, capital cost reduction and final product disposal or disposition.

Technical Memorandum 1

Flows and Loads Evaluation

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Technical Memorandum

Prepared for: City of Portsmouth

Project Title: Digester Feasibility Study

Project No.: 152936

Technical Memorandum 1

Subject: Flows and Loads Evaluation

Date: May 20, 2019

To: Terry Desmarais Jr., P.E.

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List of Abbreviations

BAF	biological aerated filters
BC	Brown and Caldwell
BFP	belt filter press
City	City of Portsmouth
CEPT	chemically enhanced primary treatment
FOG	fats, oil, and grease
lbs-TS/d	pounds-total solids per day
mgd	million gallons per day
NPDES	National Pollutant Discharge Elimination System
PDA	Pease Development Authority
PS	Primary Sludge
RBPF	Regional Biosolids Processing Facility
SBR	Sequencing Batch Reactor
TM	Technical Memorandum
TS	total solids
VS	volatile solids
WAS	waste activated sludge
WMP	2010 Wastewater Management Plan
WWTF	wastewater treatment facility

Section 1: Introduction

This Technical Memorandum (TM) 1 presents the findings of the Flows and Loads analysis for the conceptual Regional Biosolids Processing Facility (RBPF) for the City of Portsmouth (City). The City operates two wastewater treatment facilities (WWTFs), Pease WWTF and Peirce Island WWTF. The Pease WWTF treats wastewater collected from within the Pease Development Authority. The Peirce Island WWTF, treats wastewater collected from the City, portions of Rye and Greenland, and all of New Castle. The City has retained Brown and Caldwell (BC) to determine the economic viability of stabilizing and reducing the mass of biosolids generated at the Pease and Peirce Island WWTFs through the creation of a biosolids processing facility using anaerobic digestion.

Anaerobic digestion is a solids processing technology that employs microbes to break down solids and produce an energy rich biogas. The biogas can be combusted on site using combined heat and power, also known as cogeneration, energy recovery systems that produce usable electricity and heat, offsetting utility purchase costs. Additionally, anaerobic digestion reduces solids mass, creating less material to be managed, and stabilizes the solids reducing the odor generation potential. With anerobic digestion, total solids and volatile solids become key parameters in operation and design. Total solids is a measurement of the mass left after heating a sample at 110 degree Celsius; while, volatile solids is the mass of solids volatized at 550 degree Celsius. The volatile solids are considered the organic material in sludge. It is the portion that is reduced and converted into energy-rich biogas.

In addition to evaluating the financial impact from the conventional benefits listed above, this Feasibility Study includes an evaluation of a RBPF to serve as a potential merchant facility taking in solids from other publicly-owned treatment works, liquid organics from other sources such as fats, oils, and grease (FOG), and organics separated from the municipal waste stream (source-separated organics). Figure 1-1 illustrates a conceptual schematic of the RBPF.

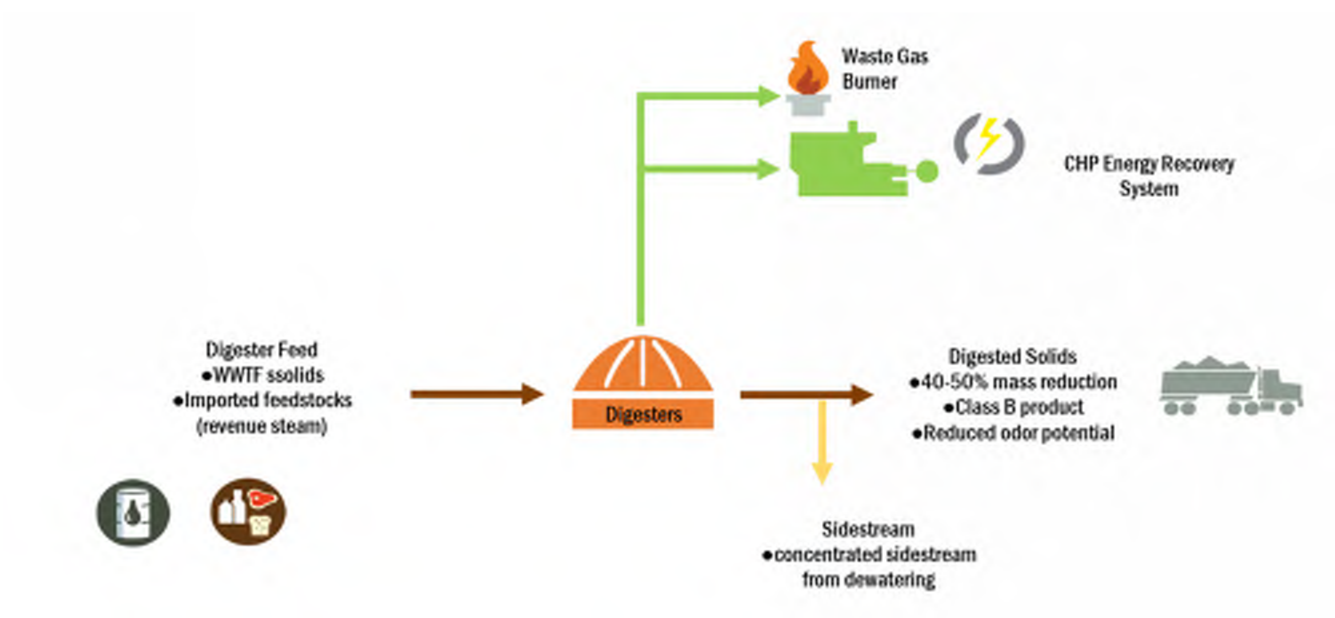

Figure 1-1. Anaerobic digestion bioenergy generation schematic

1.1 Pease WWTF Overview

The Pease WWTF is an extended aeration activated sludge facility serving domestic, commercial, and industrial users. It began operating in 1954 as a trickling filter to serve the Pease Air Force Base. With the closure of the Air Force Base in 1991, the Pease Development Authority (PDA) was established and the Pease WWTF was upgraded to meet the needs of the PDA. Soon after the upgrade, operation and ownership of the facility was transferred to the City of Portsmouth through intermunicipal agreement with the PDA. The current Pease WWTF has a treatment capacity of 1.2 million gallons per day (mgd), with industrial sewer users contributing an estimated 50 percent of the flow and 60 percent of the load to the Pease WWTF.

Shown in Figure 1-2, the current treatment process, constructed in the 1990’s, consists of a grinder and aerated grit chamber (currently being upgraded) before primary clarification. After primary settling, sequencing batch reactors (SBRs) are used for aeration and settling. Clarified wastewater is decanted from the top of the SBRs to one of two effluent flow equalization tanks, then effluent is sent to a chlorine contact tank, where flow is disinfected and dechlorinated prior to discharge to the Piscataqua River. Solids processing includes primary sludge (PS) and waste activated sludge (WAS) blended in a sludge storage tank and dewatered with a belt filter press (BFP). The Pease WWTF National Pollutant Discharge Elimination System (NPDES) permit requires secondary treatment standards but does not stipulate total nitrogen limits. However, it is anticipated that the Environmental Protection Agency may include a total nitrogen limit in a subsequent NPDES permit. The NPDES permit is based on an average monthly flow rate of 1.20 mgd but does not include a flow limit.

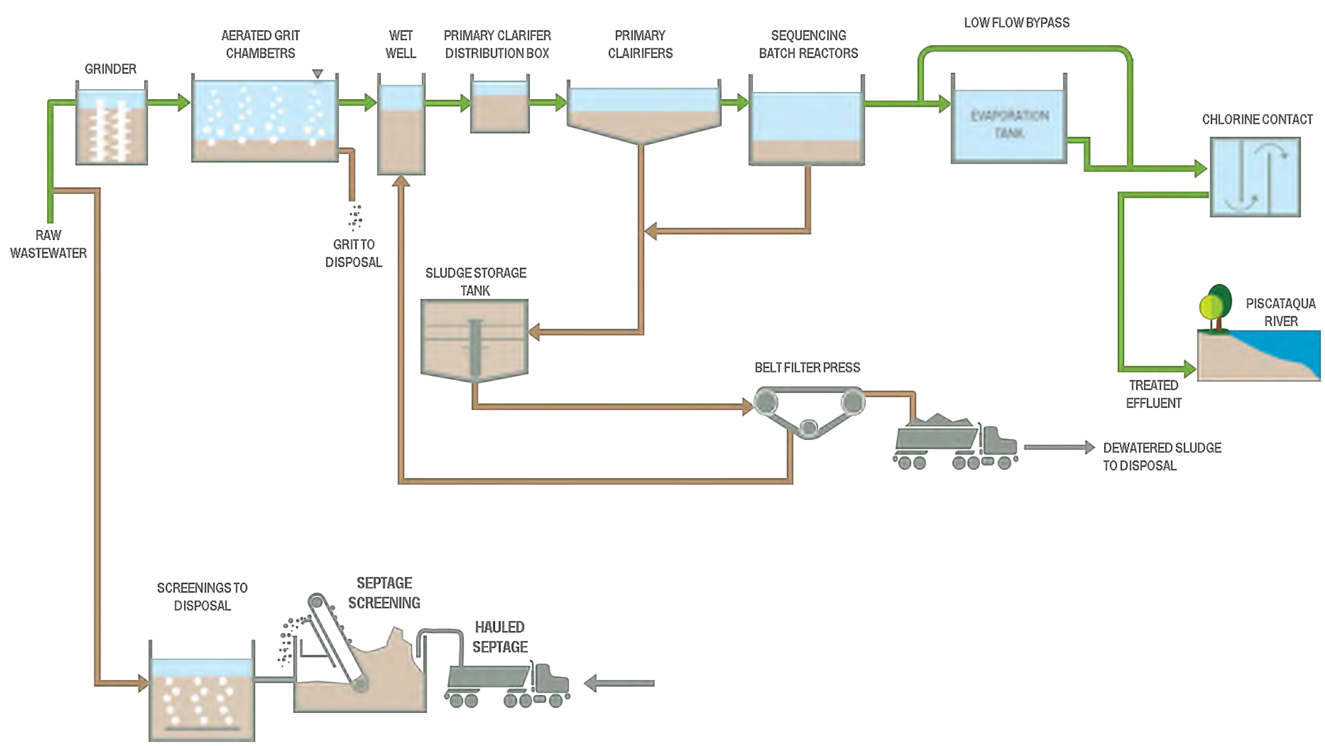

Figure 1-2. General process flow diagram of Pease WWTF

1.2 Peirce Island WWTF Overview

Constructed in the mid-1960s as a primary treatment facility, the Peirce Island WWTF has a current treatment capacity of 4.8 mgd with a peak flow of 22 mgd during wet weather. The Peirce WWTF is undergoing a major construction upgrade to an average day treatment capacity of 6.1 mgd that will include new preliminary treatment, new secondary treatment and new biosolids handling systems. Shown in Figure 1-3, the treatment process upgrades consist of raw wastewater screening, aerated grit chambers and chemically enhanced primary treatment (CEPT). To meet the secondary standards imposed in the 2007 NPDES permit and nitrogen removal requirements per Consent Decree with the Environmental Protection Agency (EPA), ongoing upgrades include a new two stage biological aerated filters (BAF) treatment process to meet secondary standards before disinfection and dechlorination prior to discharge to the Piscataqua River. Once construction is complete, the Peirce Island WWTF solids processing will consist of primary and BAF sludge that is co-thickened in gravity thickeners, and dewatered.

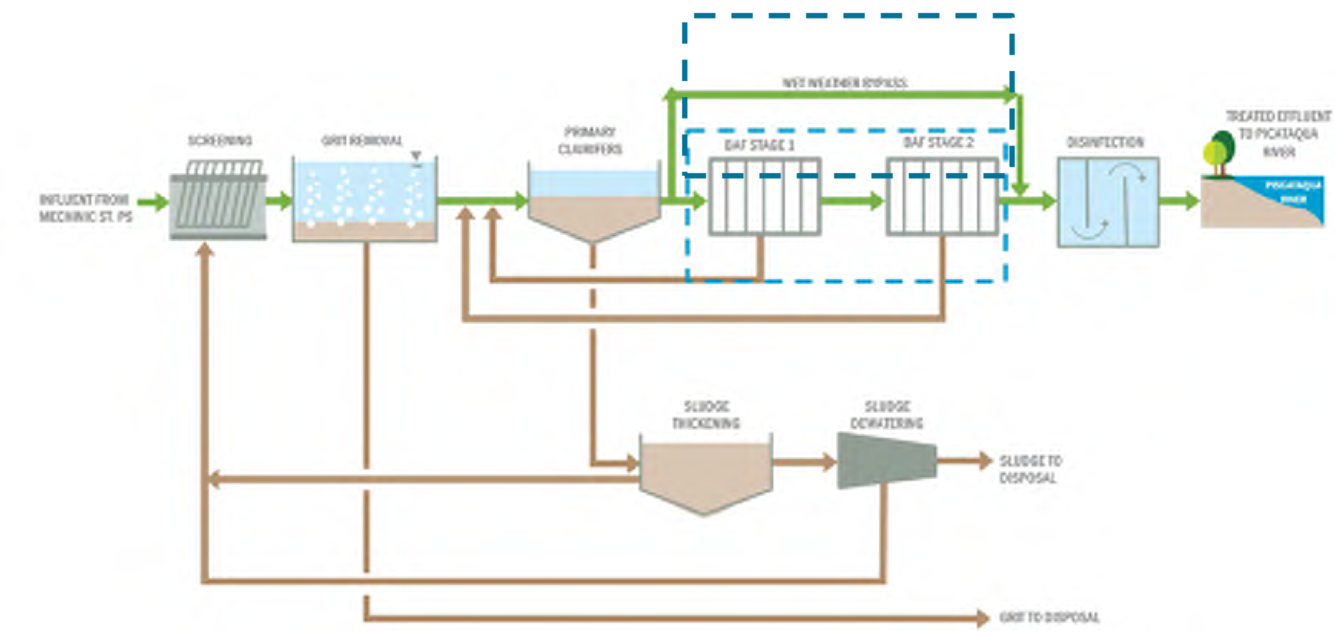

Figure 1-3. General process flow diagram of Peirce Island WWTF

Section 2: Design Flows and Loads

This section presents the current and projected flows and loads for both the Pease and Peirce Island WWTFs.

2.1 Pease WWTF

In 2010, the Waste Management Plan (WMP) evaluated flow projections for Pease WWTF, consisting of a series of TMs. TM 3 provided the flows and loading conditions for Pease WWTF, which are the data used for this analysis. The WMP projected flows and loads in 10-year increments, and this evaluation considered current (2020) conditions and future conditions under a 20-year planning period (2040). Table 2-1 summaries the current and projected average flows utilized.

Table 2-1. Flows and Loads at Pease WWTF from WMP (2010)			
	units	2020	2040
Flows	mgd	0.88	1.09
TS concentration	mg/L	403	363

2.2 Peirce Island WWTF

As Peirce Island is upgrading to BAF secondary treatment, data presented in the 2014 AECOM 30 percent design report were used for the Peirce Island analysis. From this report, the BC team used data from the existing (2013) and the future (2033) CEPT data, assuming a seasonal effluent limit of 3 mg/L of total nitrogen as presented in the AECOM data. These data are presented in Table 2-2. From these data, the 2020 (current) and 2040 (future) average flows and loads could be extrapolated. These are presented in Table 2-3.

Table 2-2. Average Flows and Loads at Peirce Island WWTF from AECOM (2014)			
	units	2013	2033
Flows	mgd	5.69	6.13
TS concentration	mg/L	167	221

Table 2-3. Average Projected Flows and Loads at Peirce Island WWTF			
	units	2020	2040
Flows	mgd	5.84	6.29
TS concentration	mg/L	184	243

Section 3: Solids Production and Handling Assessment

This section presents the current and future solids production and handling assessments.

3.1 Solids Handling Process Loadings

This Feasibility Study assumes that new digesters will be constructed at a new RBPF located adjacent to the Pease WWTF. The Peirce Island WWTF site was not considered due to lack of area for construction of a digester complex. Alternative sites were also not considered at the direction of the City, as viable sites could not be readily identified. The digester complex developed for the Pease WWTF site, and to be provided under TM 2, could potentially be used at an alternate site, if one were identified.

The loading conditions developed include:

- **Average annual.** This represents the base operating condition of the processes during a typical year. Often, service events occur during these base loading conditions, avoiding reducing capacity at peak loading conditions. For this assessment, it is assumed that the RBPF would service its digesters and other equipment at average annual flows and loads.

- **Peak 30-day average.** The peak rolling 30-day average is calculated to support the estimated impact of return stream loads on relevant facility processes.
- **Peak 14-day average.** The maximum 14-day average flow and load approximates the time frame of a primary process limitation of anaerobic digestion—a minimum solids residence time of 15 days. This loading condition is used to evaluate the peak loading condition to the digestion process, setting the firm capacity of the process. By evaluating at a marginally lower running average than the minimum SRT of the digester provides some added conservatism.
- **Peak 7-day average.** The peak maximum 7-day average.
- **Peak day.** The peak day flow and load will be used to evaluate the pumping capacity of the system, gas conveyance, and dewatering process, assuming significant peak shaving is not available through storage.

3.1.1 Pease WWTF Current and Future System Sludge Production

The average flow and loading conditions for the Pease WWTF, presented in Section 2 of this TM, were used to determine the sludge production estimates presented in Table 3-1. There were no volatile solids (VS) data provided. In the absence of data, a value was assumed that was believed to be reasonable for biological sludge.

Table 3-1. Sludge Production at Pease WWTF from WMP (2010)

	units	2020	2040
Solids Loading	lbs-TS/d	1,200	1,500
Volatile Solids Loading	lbs-VS/d	970	1,200

3.1.2 Peirce Island WWTF Current and Future Sludge Production

From AECOM (2014), the dewatered cake values were used to obtain the values presented in Table 3-2. The AECOM report did not include VS data for the PS or BAF system. The VS for PS was determined based on an evaluation by BC of three other WWTFs with combined sewer systems as 80 percent. The VS for the BAF process were based on other operating BAF facilities at 73 percent.

In addition, to obtain the primary sludge (PS) to BAF sludge ratio, BC used the AECOM primary capture rate of 74 percent, applying this capture rate to the BAF backwash sent to the head of the primaries and co-settled with PS. The resulting sludge consisted of 60 percent PS and 40 percent BAF sludge.

Table 3-2. Peirce Island WWTF Sludge Production from AECOM (2014)

	units	2020	2040
	lbs-TS/d	7,700	15,900
VS PS	lbs-VS/d	3,700	7,600
VS BAF	lbs-VS/d	2,200	4,600

3.1.3 Peaking Factors

Peaking factors for Peirce Island were calculated using the thickened sludge production data from the AECOM report for 2033 sludge. These factors are reported in Table 3-3. The BC team did not determine peaking factors for Pease WWTF or the regional facilities. For the analyses, it was assumed that Peirce Island and Pease would not peak at the same time. Also, the regional facilities would attenuate any peaks at their facilities.

Table 3-3. Peirce Island WWTF Peaking Factors					
	Average Annual	Peak 30-day	Peak 14-day	Peak 7-day	Peak Day
Factors	1.00	1.32	1.40	1.50	1.68

3.1.4 Regional Sludge Assumptions

The WMP (2010) identified several WWTFs in the region as potential sources of WWTF sludges for a RBPF. Table 3-4 presents the WWTFs in the area that are candidates to send their solids to the City's new RBPF. All values, except for Newmarket, were projected from the WMP (2010). Newmarket had a significant design upgrade to their facility in 2017 and provided updated solids estimates for this TM. There were no VS data provided. The BC team, using typical values and engineering judgment, assumed 80 percent VS for the combined sludge.

Table 3-4. Regional Sludge Production

City	State	Annual Dry Tons		%TS
		2020	2040	
Dover	NH	860	1,200	20%
Durham	NH	530	740	22.5%
Farmington	NH	440	620	19.5%
Hampton	NH	780	1,100	23%
Newington	NH	60	90	19%
Newmarket	NH	10	250	19%
Seabrook	NH	260	370	13%
Somersworth	NH	600	850	19%
Berwick	ME	560	800	25%
Kittery	ME	250	350	20%
South Berwick	ME	750	1,100	23%
York	ME	230	320	12%
Total		5,330	7,790	

3.1.5 Fats, Oils, and Grease Assumptions

The WMP (2010) identified 545,000 gallons per year of FOG available in the Seacoast area. Assuming all of this is available for the RBPF, there would be 10,500 gallons available per week. For this analysis, the BC team assumed 5 percent TS and 90 percent VS, values within the range typically observed in characterization studies for FOG. No characterization of FOG was conducted as part of this work.

3.1.6 Source Separated Organics

The City has a residential source-separated organic (RSSO) program. The organics are currently sent to the landfill. Based on information provided by the City, 35,000 pounds of RSSO per week could be collected. Assuming 30 percent TS and 80 percent VS, this equates to 1,500 pounds TS per day and 1,200 pounds VS per day, 7 days a week.

Section 4: Conclusions

Based on the flow and load analysis and the sludge production estimates, the available volume of solids for digestion at a RSPF is summarized in Table 4-1. All side stream flows and loads will be addressed in TM 2.

Table 4-1. Summary of Solids Loading to the RSPF

	2020		2040	
	TS – lbs/day	VS – lbs/day	TS – lbs/day	VS – lbs/day
Pease WWTF	1,200	970	1,500	1,200
Peirce Island WWTF	7,700	6,100	15,900	12,300
Regional Sludges	30,100	24,100	42,500	34,000
Fats, Oils and Grease	620	560	620	560
Source Separate Organics	1,500	1,200	1,500	1,200
Total	41,100	32,930	62,000	49,200

References

AECOM. *City of Portsmouth, New Hampshire Peirce Island WWTF Upgrade Design: 30% Final Design Report*. 2014

WMP. *City of Portsmouth, New Hampshire: Wastewater Master Plan: Technical Memorandum 3.* 2010

Technical Memorandum 2

Conceptual Digestion Facilities Sizing and Configuration

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Technical Memorandum

Prepared for: City of Portsmouth

Project Title: Digester Feasibility Study

Project No.: 152936

Technical Memorandum 2

Subject: Conceptual Digestion Facilities Sizing and Configuration

Date: May 20, 2019

To: Terry Desmarais Jr., P.E.

From: John Ross, P.E. (MA), Project Manager

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List of Abbreviations

AOB	ammonia oxidizing bacteria
BFP	belt filter press
DO	dissolved oxygen
DS	digested sludge
FOG	fats, oil, and grease
gal	gallon(s)
gpd	gallons per day
gpm	gallons per minute
HSW	high strength waste
kW	kilowatt(s)
kWh	kilowatt-hour(s)
lb	pound(s)
lbs-TS/d	pounds-total solids per day
MAD	mesophilic anaerobic digestion
OLR	organic loading rate
RBPF	regional biosolids processing facility
SSO	source separated organics
THP	thermal hydrolysis process
VAR	vector attraction reduction
WWTF	wastewater treatment facility

Section 1: Introduction

This Technical Memorandum (TM) 2 presents the sizing and configuration of the Regional Biosolids Processing Facility (RBPF) for the City of Portsmouth (City). The RBPF system is based on the thermal hydrolysis process (THP) with mesophilic anaerobic digestion (MAD). MAD is a biological solids processing technology that converts liquid sludge into an energy-rich biogas and a stabilized fertilizer product. Since the RBPF processes dewatered solids (assumed to be ~20% total solids), it requires a pretreatment step to dilute and adjust the solids rheology into a flowable and digestible form. THP uses pressure and temperature to process dewatered solids and adjust the sludge rheology such that it can be conveyed and digested in a highly loaded yet conventional mesophilic digester. THP also increases the overall digestibility of the solids, so that the MAD system can be loaded at a higher rate, typically requiring about half the digester volume needed relative to conventional MAD.

This TM presents the basic sizing criteria and qualitative process considerations for THP and MAD, as well as the associated major sub-systems and ancillary processes. The technologies considered for the RBPF and the general process flow is depicted below in Figure 1-1.

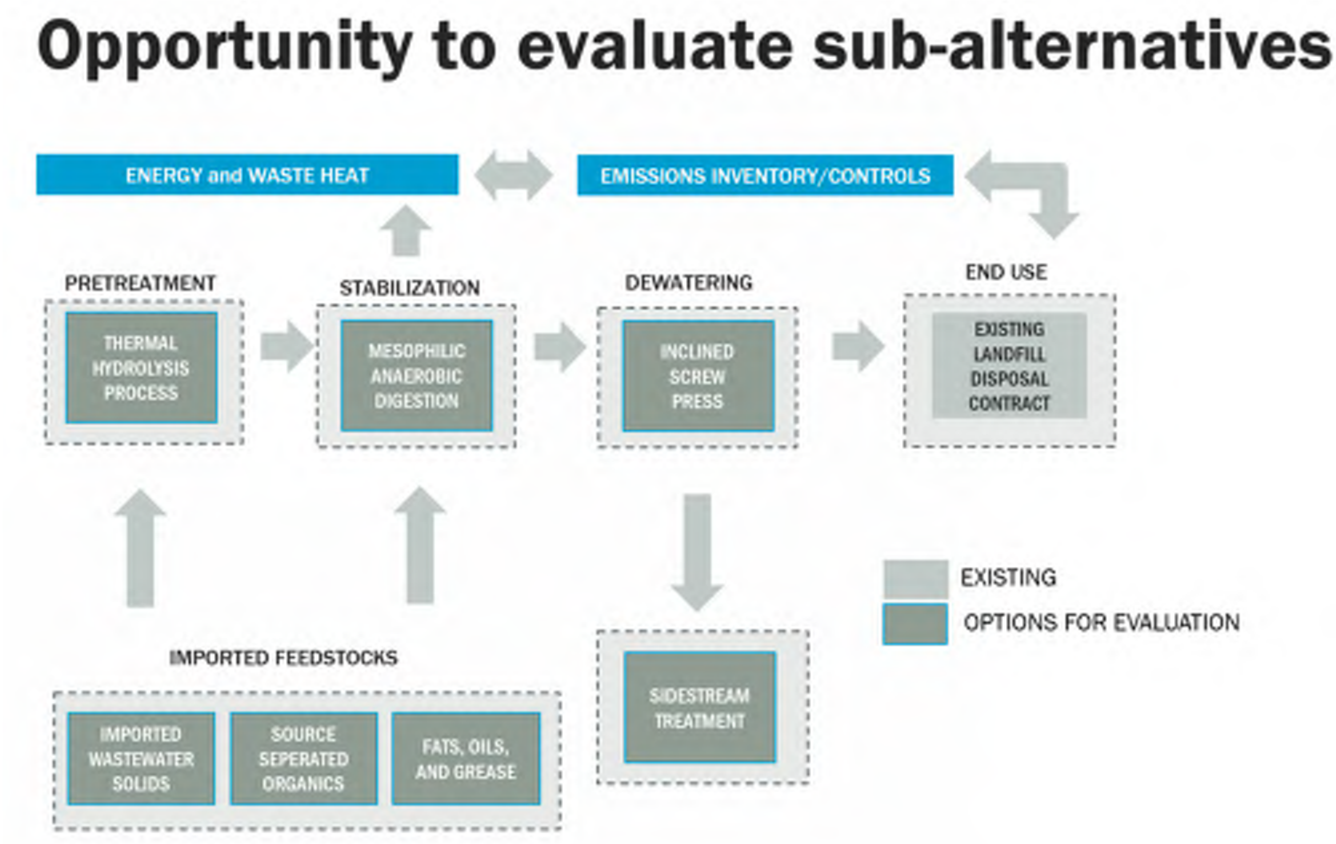

Figure 1-1. Unit processes considered for the RBPF

Given the preliminary level at which this feasibility study was conducted, an exhaustive and extensive evaluation of sub-alternatives for technologies is not provided. However, as THP is a proprietary technology and is relatively new to the United States (the first US THP installation commissioned in 2014 at the Blue Plains Advanced Wastewater Treatment Plant, Washington DC) an overview of THP technologies is provided in Attachment A. Also, an introductory evaluation of commercially available sidestream nutrient removal processes is provided in Attachment B. The import of wastewater solids and high strength wastes to the RBPF results in a significant amount of nutrient loading beyond that typically observed from conventional wastewater treatment with digestion. Attachment B provides an overview of potential solutions for nutrient control outside of mainstream treatment enhancements.

Representative technologies for each unit process were selected to provide a basis for cost and reference facility footprint. If the project is advanced, it is recommended that a detailed analysis of nutrient impacts and biosolids handling and processing technology selection be performed with the next step. Operational and process efficiency improvements may be available with installation of different types of equipment.

Section 2: Biosolids Handling and Processing Technologies

2.1 Fats, Oils and Grease (FOG) and Source Separated Organics (SSO) Receiving

Two of the main considerations for implementing a high strength waste (HSW) (i.e. FOG, SSO, and potentially liquid industrial wastes) receiving program are managing grit and debris and on-site storage. FOG often contains high levels of rags and debris that need to be removed to protect downstream processing and biosolids quality. Storage is required to prevent slug-loading digesters with the HSW, which can cause process upsets, imbalances in gas production and volume expansion. It was assumed that the SSO would be pre-processed material suitable for anaerobic digestion and that additional onsite pre-processing is not required. Figure 2-1 depicts examples of HSW receiving station designs.

Trucked waste offloading at Iona Island WWTP | FOG Receiving Screen pilot at HRSD wastewater plant | Gresham, OR FOG receiving station

Figure 2-1. Example FOG receiving station designs at municipal WWTFs

One strategy for grit and debris management is to use a packaged offloading and screening system. The Enviro-Care™ BEAST is an example of the technology that integrates the truck offloading connection, hauler control station, and automated screen into one packaged system. The hauler station contains an electrically actuated inlet valve, magnetic flow meter, hauler access panel, and software to operate and track the system's operation. Figure 2-2 depicts a representative BEAST receiving station installation.

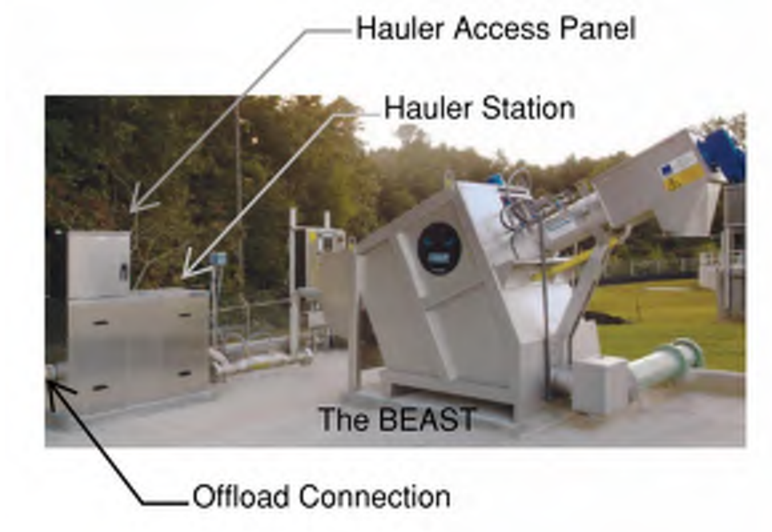

Figure 2-2. Enviro-Care™ BEAST Receiving Station

Courtesy of Enviro-Care™

BC assumed a single comparable screening system would be used to receive the HSW and that storage would be provided in a downstream blending tank used to homogenize feed of materials to the digester. The quantity of HSW material and receiving station operational parameters developed from TM 1 are provided below in Table 2-1. As the commercially automated screening units are capable of offloading multiple trucks in an hour, only one unit was included in the conceptual design for this study.

Table 2-1.HSW Receiving Parameters

	TS (lb/d)	Volume (gpd)	Trucks/d*
FOG	623	1,490	1
SSO	1,500	1,800	1

Assumes trucks received 5 days per week with 3,000 gallon tanker trucks

2.2 Imported Dewatered Solids Receiving

Two programmatic options exist for implementing a regional wastewater solids digestion system. The first is to work with regional wastewater treatment facilities (WWTFs) and haulers to abandon existing dewatering operations and establish liquid sludge only receiving agreements. This requires additional stakeholder coordination, but results in a relatively simple receiving operation at the RBPF. Generally, all that is required are quick connects and offloading pumps to transfer the sludge to digester feed tanks.

Conversely, receiving and processing dewatered solids (cake) on site allows the regional WWTFs that dewater to continue with status quo operation, which consequently reduces truck traffic and hauling costs for the regional facilities. Without receiving agreements from regional WWTFs to haul liquid sludge, this study included a dewatered solids receiving and rewetting system sized to adequately handle the solids projections from TM 1. Examples of commercially available trucked cake receiving stations are shown below in Figure 2-3 for reference.

Figure 2-3. Trucked cake receiving stations

Courtesy of Schwing Bioset and Putzmeister

Regional facilities, such as The Metropolitan District Commission's plant in Hartford, Connecticut currently take imported wastewater cake and dilute it down for addition to the solids thickening train to equalize loading to a regionalized incinerator. However, there are no facilities within the region that receive dewatered cake and slurry it for feed into an anaerobic digester. In the industry, THP systems are growing in popularity as a means to break down dewatered cake, changing its consistency into a pourable liquid that can be fed directly to digestion as described in the next section. The quantity of dewatered cake projected for the RBPF (regional sludge, Pease WWTF, and Peirce Island WWTF) and cake receiving operational parameters developed from TM 1 are provided below in Table 2-2. The study assumes a single receiving bunker for the facility as each bunker has the capacity to receive multiple truckloads within an hour and can transfer the sludge cake continuously at rate of 26 wet tons per hour.

Table 2-2.Cake Receiving Parameters

	TS (lb/d)	Volume (wet tons/d	Trucks/d
Current regional sludge + Pease + Peirce (2020)	37,780	105	6
Future regional sludge + + Pease + Peirce (2040)	58,380	162	9

assuming trucks received 5 days per week with 25 ton tanker trucks and 18%TS cake

2.3 Thermal Hydrolysis Process

THP is a pre-digestion conditioning process that makes feed solids more amenable to digestion. The process uses elevated temperature and pressure to lyse bacterial cells and promote the release and solubilization of particulate organic material, THP systems can approximately double MAD organic loading rates (OLR) because of the modified characteristic of the feedstocks. This more efficient use of digester volume reduces the number of digesters required. Ancillary buildings and equipment are required to operate a THP system, including steam boilers, pre-dewatering if the feed sludge requires dewatering, raw cake storage, and sludge cooling systems. While THP systems can reduce digester volume required, these ancillary systems impact total system cost, complexity, and footprint.

The vast majority of THP systems have been implemented by Cambi and these systems use medium-pressure steam to create the high temperature and pressure conditions in batch reactors. Producing medium-pressure steam is often a deterrent for small to mid-size WWTFs given the additional operator safety and licensure requirements. Lystek is an alternative THP technology provider that uses lower-temperature heat, high shear mixing, and alkali for pH adjustment to facilitate hydrolysis. Lystek uses low pressure steam and a non-pressurized reactor vessel, lowering the operational barrier for THP. Given the reduced operational burden and Lystek's growing list of successful full-scale facilities (11 worldwide) it was selected as the representative THP technology for the RBPF.

For the conceptual facility design, dewatered cake discharged into the receiving bunkers is mixed with water in the transfer pump discharge lines to achieve a target total solids (TS) content. The diluted material is then conveyed into a live-bottom storage bin. Another series of screw conveyors and positive displacement pumps deliver the material from the storage bin to reactor tanks. Two parallel reactor tanks are required to process the material at the combined solids projections identified in TM 1. Steam from boilers and quick lime are added to the solids in the reactors to raise the temperature and pH. A mixer mounted on the top of each reactor blends the material.

Treated sludge is then cooled and transferred to the digester feed blend tank to homogenize all digester feed materials before they are introduced into the MAD system. Another option for the future system to consider is also providing a batch holding tank where the treated material could be held at temperature to achieve Class A time-temperature requirements. Lystek could be engaged to locate and distribute the undigested Class A product, or processed sludge could continue on to digestion and the digested sludge could then be managed as a Class A product.

A conceptual Lystek THP facility description is provided below in Table 2-3 and a layout is depicted below in Figure 2-4.

Table 2-3. Lystek Process Components

Element	Quantity	Function
Dewatered biosolids storage hoppers	2	Receives and stages dewatered biosolids from dewatering equipment for processing within the Lystek Reactors
Dewatered biosolids feed pumps	2	Positive displacement pump feeds the semi-continuous Lystek Reactors
Lystek THP Reactors and Disperses	2	Transforms biosolids into hydrolyzed concentrated liquid product
Reactor discharge pumps	2	Positive displacement pumps transport hydrolyzed biosolids from the Reactors to digestion
KOH Storage Tanks	1	Double walled storage tank to store alkali
KOH Pumps	2	Doses alkali to Lystek Reactors
Boilers	1	Low pressure boilers (<15 PSI) provide steam heat to the Lystek Reactors

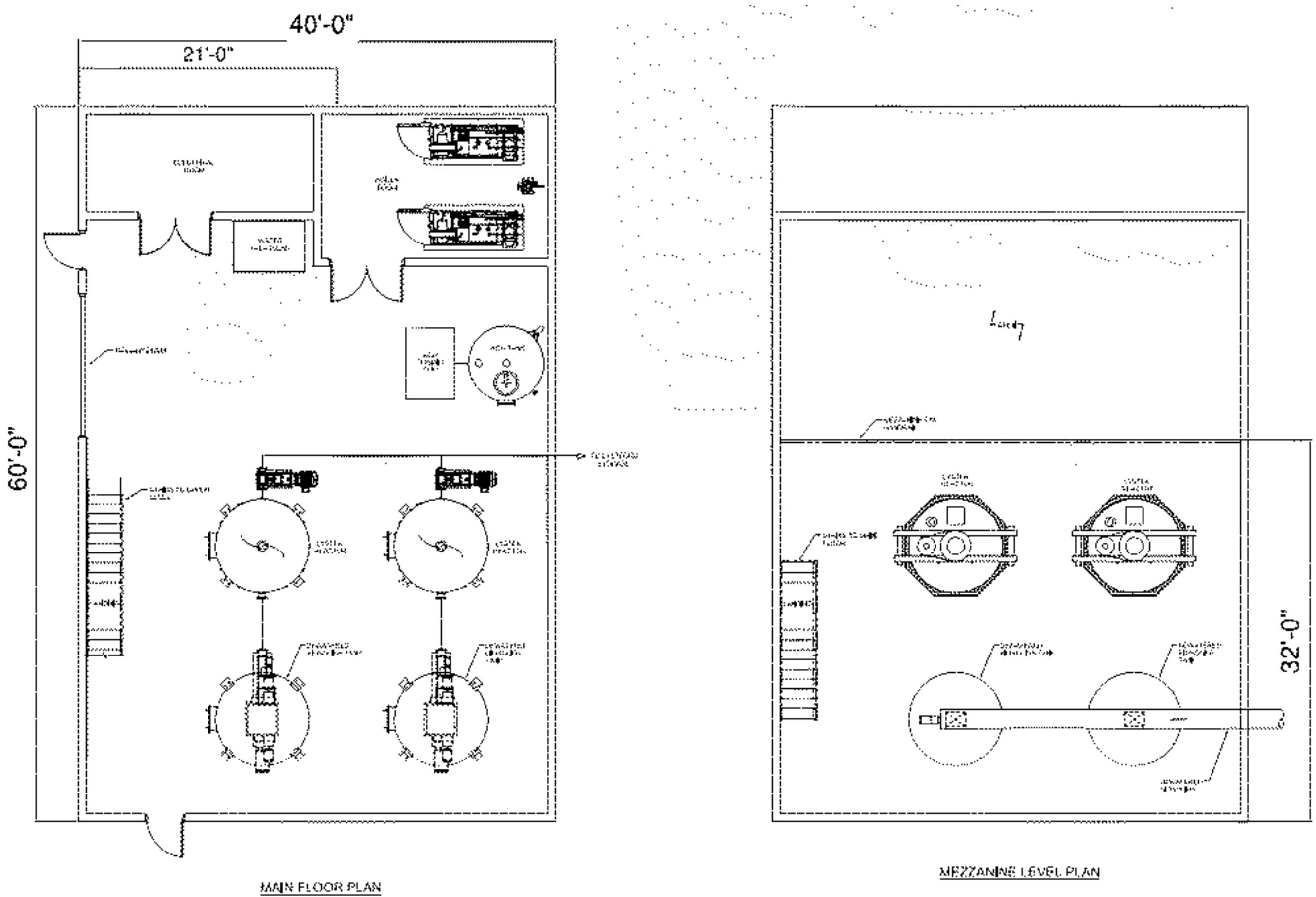

Figure 2-4. Conceptual Lystek Facility Layout

Courtesy of Lystek

2.4 Mesophilic Anaerobic Digestion

This feasibility study considered conventional mesophilic anaerobic digestion as the primary sludge stabilization and bioenergy generation technology. Mesophilic anaerobic digestion employs operating temperatures between 95 and 102°F and digests solids under anaerobic conditions. This stabilization process has the longest operational history of all the digestion technologies, with the most supporting operational data to date. It represents the standard digestion technology configuration and has the advantages of being non-proprietary and having a proven track record.

Figure 2-5. Conventional mesophilic digester at the City of San Diego, California

The performance of anaerobic digesters is improved by providing uniform and well-mixed conditions within the digester. The digester contents are mixed by gas recirculation, pumping, or draft-tube mixers. Continuous feeding to the digesters is preferred, or at a minimum on a 30-min to 2-hr time cycle to help maintain consistent conditions in the digester. Digesters may have a fixed, floating, or gas membrane cover. Floating and membrane covers can provide excess gas storage, while for a fixed cover, the biogas may be collected and stored in a separate gasholder. Digesters may also be configured in an egg-shape to reduce dead zones in the reactor as well as liquid surface area and corresponding scum buildup. The egg-shaped digesters at the Massachusetts Water Resources Authority's Deer Island Treatment Plant are shown below in Figure 2-6.

Figure 2-6. Egg-shaped digesters at the Deer Island Treatment Plant, Boston, MA

Typically, as described in TM-1, MAD systems are operated at a minimum SRT of 15 days which, when requirements for vector attraction reduction (VAR) are met, guarantees Class B pathogen status, allowing for beneficial reuse in land application. Pathogen classes (A and B) and VAR designations are defined in 40 CFR Part 503 and determine the type of land onto which different types of biosolids may be applied. Class B biosolids have less stringent pathogen destruction demonstration requirements than Class A, but greater restrictions for land applications.

The RBPF digester gas energy recovery system is discussed in TM 3. The operational parameters for the CBPF and for a reduced size MAD system, sized to handle Pease WWTF and Peirce Island WWTF sludge only is provided below in Table 2-4.

Table 2-4. MAD Facility Sizing Parameters

	2040 Annual Average Loading		Digestion Facility Sizing	
	Dry mass (lb/hr)	Hydraulic (gpm)	Quantity	Tank size (MG)
Pease + Peirce Island WWTF only	790	16	2	1.0
Regional Digestion	2,810	56	3	1.4

2.5 Dewatering Technology

Inclined screw press technology was selected to provide the additional dewatering capacity required for the RBPF. Screw presses are a relatively new technology compared to centrifuges and belt filter presses (BFP). However, there are many installations in North America, and specifically, in New Hampshire. A screw press is a conical screw shaft surrounded by cylindrical sieves. As the screw rotates, the sludge slowly moves along the shaft and water is pressed out through the sieves. Screw press manufacturers state that this technology offers less maintenance, lower wash water consumption, and lower energy consumption.

The dewatering system throughput is provided below in Table 2-5. The solids loading indicates that a single large screw press can be used to handle the loading on a 24 hr/d, 5 d/wk basis. Multiple screw presses would be required if a smaller size is installed, or a reduced operating schedule is desired. It was assumed that the new dewatering system would include the current BFP as a standby unit and so to accommodate the additional space requirements a new dewatering facility would be required.

Table 2-5. Dewatering Facility Parameters

	Peak Day TS (lb/hr)	Volume Hauled (wet tons/d	Trucks/d
Future regional sludge (2040)	2,290	108	6

Assuming unattended dewatering operation, 24 hr/d and 5 d/wk; trucks haul cake 5 days per week with 25 ton transport trucks and 18%TS cake

Section 3: Conceptual Layout of Solids Handling Facilities

Concurrent with evaluating the technical viability of the RBPF, a conceptual design layout was developed to determine if the Pease WWTF site could accommodate the infrastructure and identify potential logistics surrounding facility construction. Using a combination of City input, BC experience, and process analysis results, a conceptual facility layout was developed and is illustrated below in Figure 3-1. This study evaluated the land available near the Pease WWTF and did not consider implementation of an offsite facility given the additional complexity and cost associated with identifying and purchasing the land. Any future evaluation for an offsite RBPF would have to factor in the additional cost to acquire the property for the facility and obtain the necessary permits.

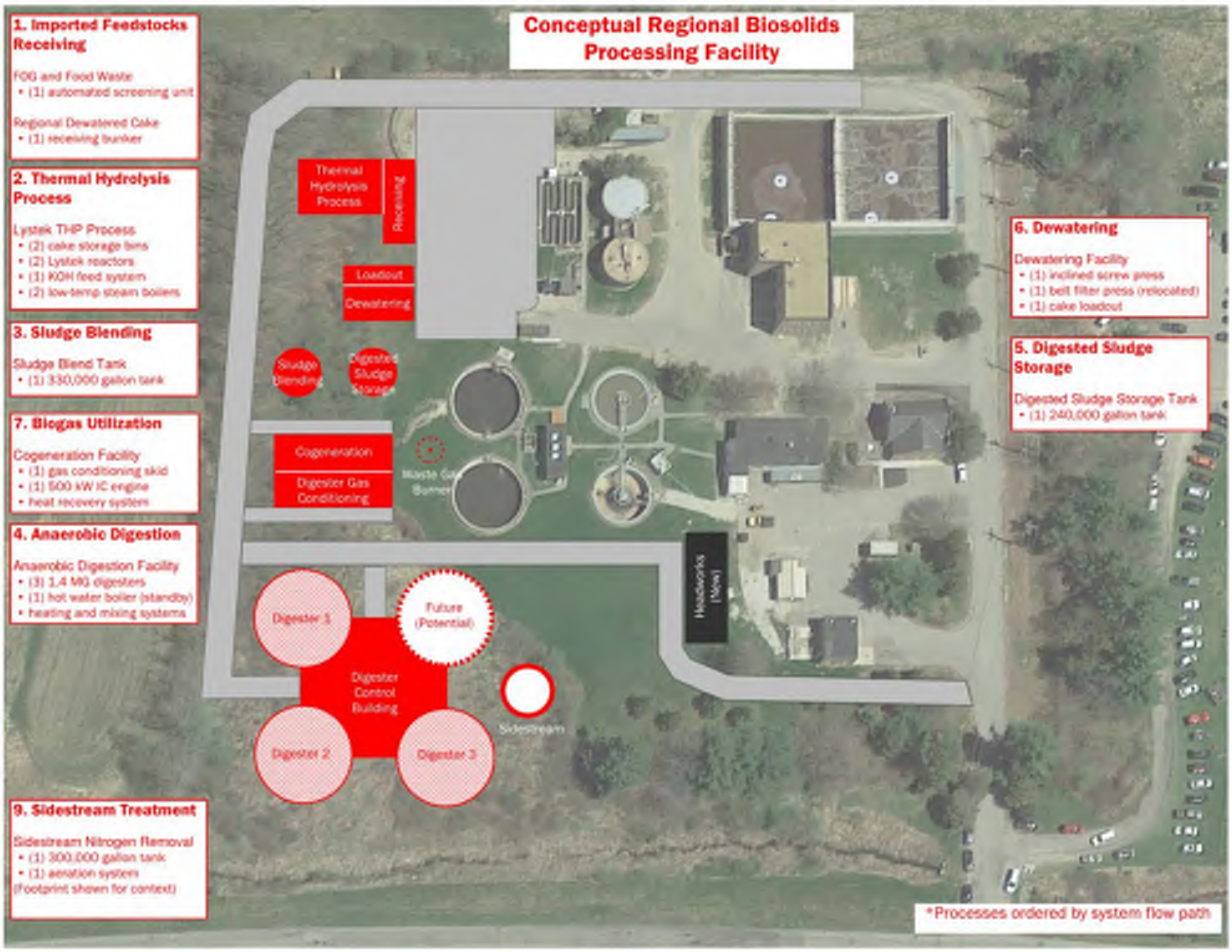

Figure 3-1. RBPF Layout at the Pease WWTF site

The imported feedstock receiving stations are shown alongside a large truck pad at the north end of the WWTF. There is enough space to set the truck pad such that the offloading trucks can pull in and back up to the receiving area easily. The HSW receiving equipment is located at grade adjacent to the imported cake receiving bins. The THP facility is located next to the receiving area and the THP-processed cake and HSW are transferred to the sludge blending tank to the south.

The three digesters are configured in a typical quad configuration, leaving room for a potential fourth digester in the future if additional capacity is required. The gas conditioning, energy recovery, and waste gas burner station are located north of the digesters. Access roads are provided to the gas conditioning and cogeneration building while a 10-foot clearance is maintained around the flare to meet current design codes and standards. A sidestream treatment system is also depicted to provide a representative footprint if this technology is required to meet future nutrient limits. Sizing and pricing of a sidestream system was not part of the feasibility study as it depends on the status of future limits, which limits were unknown at the time of this study. However, based on other projects in the area a sidestream system could cost between $7M to $13M, size and technology dependent.

The new RBPF facilities are shown in areas identified as wetlands by the City. Construction in these areas may require additional measures, such as wetland offset trading as well as City, State and Federal approvals. Other considerations for the site include planning and zoning reviews, local building permits, permitting for construction practices, and approval from the Pease Development Authority. Additional site review requirements such as historical resource review and endangered species review may also apply. The potential air permitting implications for the digester gas energy recovery system are discussed in TM 3.

Attachment A: THP Treatment Technologies

THP Treatment Technologies

THP is an anaerobic digestion pretreatment system that results in more efficient wastewater solids processing and energy production and, in certain configurations, achieves Class A biosolids. This attachment provides a description of the major types of THP systems and technology providers.

A.1 Class A THP

Class A THP is a mature technology in world-wide with full-scale facilities in service since 1995; the first installation in the United States (DC Water) has been operating since late 2014 and other U.S. installations are in the planning, design, and construction phases. There are three primary manufacturers of Class A THP – Cambi, Veolia, and Lystek. Class A THP typically uses medium-pressure steam to create high temperature and pressure conditions, which lyse bacterial cells and promote the release and solubilization of particulate organic material, making the feed solids more amenable to digestion. Lystek is able to use a low-pressure steam system with pH adjustment of the reactor Figure A-1 below depicts a typical process flow of the Cambi Class A THP system. THP can also be used in a WAS-only configuration, where it would generate Class B biosolids.

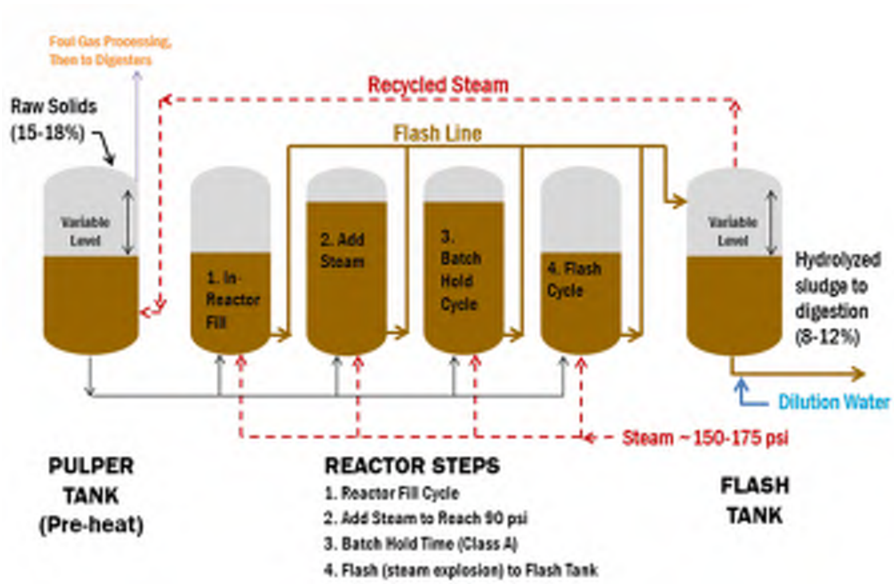

Figure A-1. Cambi thermal hydrolysis process.

The vast majority of Class A THP systems have been implemented by Cambi. However, competitor THP systems have been installed in Europe, and Veolia's Biothelys system has been installed in the United Kingdom and Lystek in Canada and the United States. THP systems can approximately double MAD OLRs because of the modified characteristic of the feedstocks. This more efficient use of digester volume reduces the number of digesters required. Ancillary buildings and equipment are required to operate a THP system, including steam boilers, pre-dewatering centrifuges, raw cake storage, and sludge cooling systems. While THP systems can reduce digester volume required, these ancillary systems impact total system cost, complexity, and footprint.

A.1.1 Exelys Digestion-Lysis-Digestion

Exelys-DLD is a process developed by Veolia. While many THP systems use a batch process, Exelys uses a continuous flow reactor. In the DLD configuration, hydrolysis does not occur on the digester feed. Hydrolysis is placed between two digestion steps instead of prior to digestion, as shown in Figure A-2. This configuration helps digestion by hydrolyzing solids that are resistant to digestion. The readily digested material has already been digested in the first digestion stage, leaving only the harder-to-digest organics. This material is now more digestible in the second-stage digester. Relative to MAD, this system would produce more biogas and destroy more solids. The process requires more digestion tankage than more common THP approaches and does not have full-scale installations in North America.

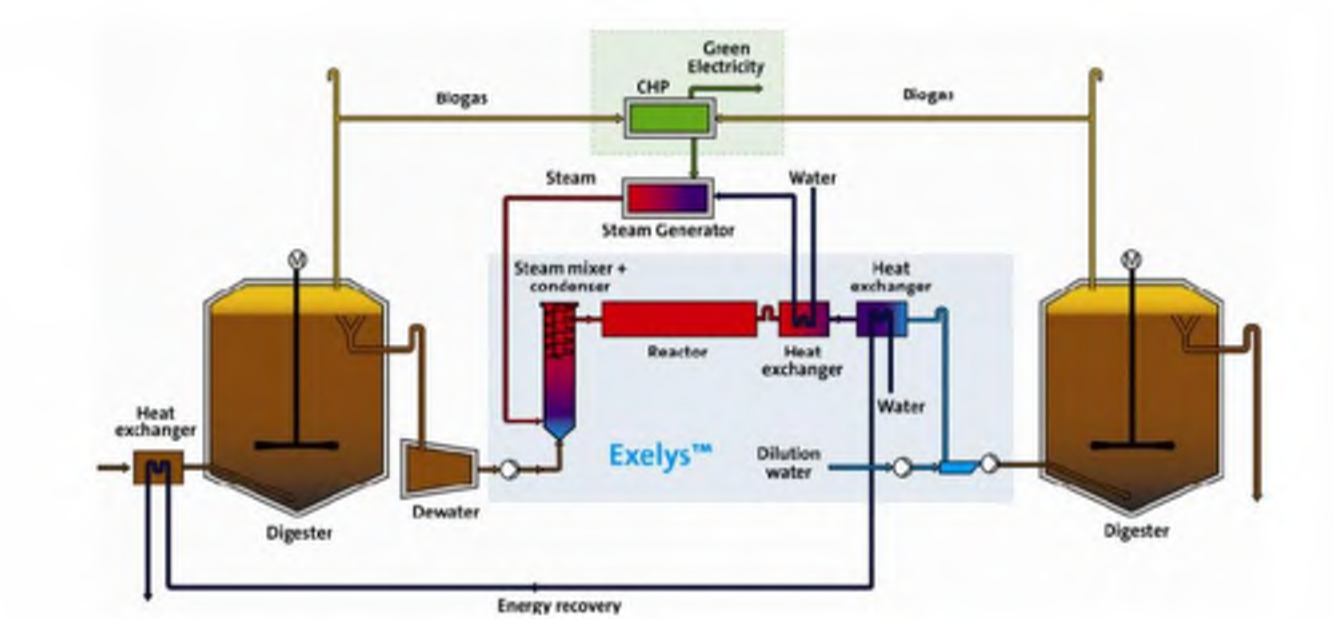

Figure A-2. Exelys digestion-lysis-digestion process.

Source: Veoliawatertech.com

A.1.2 SolidStream Cambi

SolidStream Cambi is different from Cambi's traditional Class A THP in that it does not hydrolyze the solids prior to digestion. The sludge is digested in a digester, such as MAD, and then the digested sludge (DS) is dewatered. Dewatered sludge enters the SolidStream system where it is hydrolyzed and final dewatered as a hot material. In this process, the dewaterability of the sludge is increased by increasing the temperature and pressure. This degrades the extracellular polymeric substances, which causes the release of more water from the sludge. Immediately following hydrolyzing, the solids are dewatered using a centrifuge without the addition of polymer. The centrate is fed to the digester and cake can be a Class A material. Figure A-3 provides an overview of this process. The benefit of SolidStream Cambi is the increased dewaterability of the solids and the additional soluble COD from the centrate can increase gas production. This technology has yet to be installed in North America and it has not been demonstrated on the scale of the CRBPF.

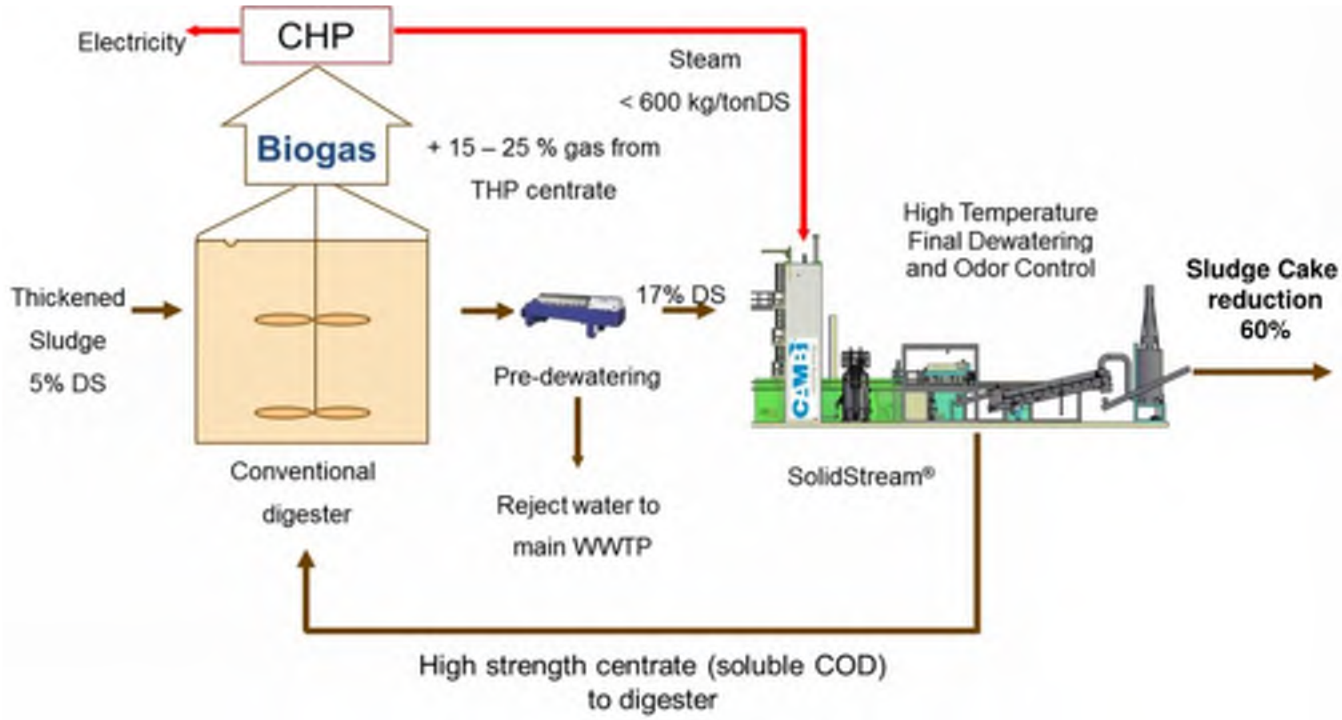

Figure A-3. SolidStream Cambi process.

Source: [*http://www.cambi.com/Products/Cambi-SolidStream*](http://www.cambi.com/Products/Cambi-SolidStream)

A.1.3 Enzymatic Hydrolysis

Enzymatic hydrolysis is a stabilization method that enhances enzyme activity of the anaerobic bacteria by using six serial reactor vessels. The initial enzymatic hydrolysis process tanks operate between 95°F and 108°F with short detention times (e.g., 3 days) to promote acidogenic bacterial growth. The subsequent process tanks can operate at upwards of 95°F, which promotes the growth of methanogens.

The company Monsal (www.monsal.com) is the major technology provider in Europe with about 11 reference installations in the United Kingdom. Monsal claims that its high-rate hydrolysis technology and equipment can be retrofitted to existing digestion plants for upgrade or developed as part of new build turnkey digestion plants. Claimed key benefits of Monsal advanced digestion technology include: (1) high digester loading greater than 0.19 to 0.38 lb-VS/ft^3-d; (2) improved solids dewatering—up to 30 percent DS; and (3) high biogas yields. This technology has not been installed full-scale in North America.

A.1.4 Thermo-Chemical Hydrolysis

The thermo-chemical hydrolysis process uses chemicals and elevated temperature to expedite the hydrolysis step. The major technology provider is CNP Technologies and its Pondus TCHP process. CNP currently operates a full-scale pilot operation at the Kenosha WWTP in Kenosha, Wisconsin.

TCHP is designed to focus on TWAS pretreatment. In this process, TWAS is mixed with caustic soda (1,500 to 2,000 parts per million [ppm]) to reach a pH of approximately 11. TWAS is then heated to thermophilic temperatures (150°F to 160°F), using heat exchangers prior to being fed to the reactor. Detention time of the reactor is between 2.0 and 2.5 hours, during which the hydrolysis breaks down the cell walls and releases internal organic acids. The hydrolyzed sludge is then sent to the digesters for digestion. The Pondus TCHP has seen reported benefits of higher VSR, biogas production, and dewaterability of cake.

A.1.5 Lystek

Lystek is a Canadian company with several full-scale installations in Canada and two full-scale installations in the United States. Lystek uses a thermochemical hydrolysis process that hydrolyzes either digested or raw sludge. The system uses a combination of heat (158-167°), pH 9.5-10.0 using KOH/NaOH and high shear mixing for up to 45 minutes. The result is a high-solids (14-17%), liquid product (<5,000 cP) that can be used as a Class A EQ fertilizer or continued to anaerobic digestion. Additionally, the system can also be used to process digested solids, making them amenable to further digestion, improving biogas yield and reducing volume. . The treated product can also be used as a carbon source for biological nutrient removal.

Lystek opened its first U.S. installation in Fairfield, California, in 2016. This is a regional facility treating solids from several Bay area WWTFs, roughly equivalent to the solids production from a 150 mgd treatment plant.

Attachment B: Sidestream Nutrient Removal Processes

Nutrient Recycle Analysis

A liquid stream evaluation was conducted to provide a high-level comparison of operations based on Peirce Island WWTF and Pease WWTF sludge only and the RBPF scenario including imported organics, i.e., food waste and FOG, feedstock options. A process model was created and run based on assumptions from existing operations at the Pease and Pierce Island WWTFs. Current nitrogen concentrations and assumptions based on BC experience and case studies for the indigenous sludge, imported sludges, food waste and FOG were used to predict the amount of nitrogen and phosphorous that will be released during anaerobic digestion and co-digestion (based on VSr) and after dewatering (based on capture rate and solids concentrations). Values used in the model for raw sludge and organics (food waste and FOG) nitrogen and phosphorous content are presented in Table B-1 and Table B-3, respectively.

Table B-1. Raw sludge and organics nitrogen content	
Peirce Primary Sludge	
Organic Nitrogen Content sludge (mg-N/mg-TS)[a]	0.024
Sol. Nitrogen Content sludge (mg-N/mg-TS)[a]	0.103
Peirce BAF Sludge	
Organic Nitrogen Content sludge (mg-N/mg-TS)[b]	0.010
Sol. Nitrogen Content sludge (mg-N/mg-TS)[b,c]	0.045
Pease Sludge	
Organic Nitrogen Content sludge (mg-N/mg-TS)[c]	0.024
Sol. Nitrogen Content sludge (mg-N/mg-TS)[d]	0.126
Outside Cake	
Organic Nitrogen Content sludge (mg-N/mg-TS)[c]	0.024
Sol. Nitrogen Content sludge (mg-N/mg-TS)[d]	0.126
Food Waste	
Organic Nitrogen Content FW (mg-N/mg-TS)[e]	0.029
Sol. Nitrogen Content FW (mg-N/mg-TS)[e]	0.002
FOG	
Organic Nitrogen Content FOG (mg-N/mg-TS)[e]	0.045
Sol. Nitrogen Content FOG (mg-N/mg-TS)[e]	0.004

a. *Calculated based on historical data provided by City of Portsmouth Staff*
b. *Calculated based on data from July 2014 AECOM Report*
c. *Assumed sludge characteristics are similar to Peirce Island WWTF primary sludge*
d. *Calculated based on data from 2015 Arcadis Report and Peirce Island WWTF primary sludge characteristics*
e. *Based on values from Brown and Caldwell Study with the City of Tacoma*

Table B-2. Raw sludge and organics phosphorous content	
Peirce Sludge	
Organic Phosphorus Content sludge (mg-P/mg-TS)[a]	0.021
Sol. Phosphorus Content sludge (mg-P/mg-TS)[b]	0.004

Table B-2. Raw sludge and organics phosphorous content	
Peirce BAF Sludge	
Organic Phosphorus Content sludge (mg-P/mg-TS)[a]	0.021
Sol. Phosphorus Content sludge (mg-P/mg-TS)[b]	0.004
Pease Sludge	
Organic Phosphorus Content sludge (mg-P/mg-TS)[a]	0.021
Sol. Phosphorus Content sludge (mg-P/mg-TS)[b]	0.004
Outside Sludge	
Organic Phosphorus Content sludge (mg-P/mg-TS)[a]	0.021
Sol. Phosphorus Content sludge (mg-P/mg-TS)[b]	0.004
Food Waste	
Organic Phosphorus Content FW (mg-P/mg-TS)[c]	0.0017
Sol. Phosphorus Content FW (mg-P/mg-TS)[c]	0.0027
FOG	
Organic Phosphorus Content FOG (mg-P/mg-TS)[c]	0.0018
Sol. Phosphorus Content FOG (mg-P/mg-TS)[c]	0.0022

a. *Total P assumed to be 2.5% of the sludge total solids content*
b. *Based on Soluble Ortho-P concentrations from UMass Study*
c. *Based on values from Brown and Caldwell Study with the City of Tacoma*

The model was used to predict the amount of nitrogen and phosphorous recycled to the head of the plant in the digested sludge filtrate streams. The model baseline operation includes Pease WWTF sludge under current operations (without digestion) including dewatering. The RBPF scenario was set to model the baseline plus the addition of Pierce Island WWTF sludge, imported sludge, and organics, including food waste and FOG, as described in TM 1. The model results are presented in Table B-3.

Table B-3. Plant Influent Impacts of Nutrient Recycle

	Average Annual	Max 30 Day	Max 14-Day	Max 7	Max Day
Plant Influent					
Peaking Factors for Pease	1.00	1.26	1.40	1.50	1.69
Influent Pease Flow (MGD)	0.59	0.74	0.82	0.88	0.99
Influent TKN (mg-N/L)	41	41	41	41	41
Influent Phosphorus (mg-P/L)	10	10	10	10	10
Pease Plant Load (lb-N/day)	198	249	277	297	335
Pease Plant Load (lb-P/day)	49	62	68	73	83
Baseline					
Filtrate Return N Load (lb-N/day)	**1,115**	**1,083**	**1,184**	**1,255**	**1,391**
Filtrate Return P Load (lb-P/day)	**47**	**52**	**57**	**61**	**68**
Filtrate Return Load- Percent of Pease Plant N Load (%)	563%	434%	427%	423%	416%
Filtrate Return Load- Percent of Pease Plant P Load (%)	97%	85%	84%	83%	82%
RBPF					

Table B-3. Plant Influent Impacts of Nutrient Recycle

	Average Annual	Max 30 Day	Max 14-Day	Max 7	Max Day
Filtrate Return N Load (lb-N/day)	**6,520**	**6,461**	**6,577**	**6,660**	**6,817**
Filtrate Return P Load (lb-P/day)	**806**	**780**	**802**	**818**	**847**
Filtrate Return Load- Percent of Pease Plant N Load (%)	3294%	2591%	2374%	2243%	2038%
Filtrate Return Load- Percent of Pease Plant P Load (%)	1650%	1267%	1172%	1115%	1026%

Operation at the baseline and RBPF resulted in a filtrate return N load of 1,115 lb-N/d and 6,520 lb-N/d, respectively. For phosphorous, the analysis resulted in a filtrate return P load of 47 lb-P/d and 806 lb-P/d for the baseline and RBPF, respectively. The addition of Pierce Island WWTF sludge, imported sludge, and organics (food waste and FOG) results in a substantial increase in the nitrogen and phosphorous recycled back to headworks under the RBPF. The analysis shows that in addition to operational benefits that would result from the addition of imported sludge and organic wastes, the City will also need to consider some form of sidestream treatment at the Pease WWTF for additional nitrogen and phosphorous release during anaerobic co-digestion. BioWin modeling is recommended to examine whole plant impacts with the addition of such high N and P loads to the Pease WWTF.

Sidestream Nitrogen Removal Processes

Many side stream nitrogen removal processes have been developed over the past decade in response to reducing the cost of mainstream nitrogen removal. They include both biological and physical-chemical processes although biological processes now dominate the market place. Physical-chemical processes include air stripping and absorption and ion exchange. Only the stripping/absorption process has been commercialized, primarily in Europe. Biological processes include (i) complete nitrification and denitrification, (ii) so-called short-cut or shunt nitrogen removal technologies in which nitrification is permitted to proceed only to nitrite, which is then denitrified, and (iii) the deammonification technology. The last option is mediated by a special class of bacteria (ANaerobic AMMonia OXidation, or anammox bacteria). Deammonification requires the partial nitritation of ammonia by ammonia-oxidizing bacteria followed by anaerobic autotrophic ammonium oxidation to produce nitrogen gas.

When there is projected to be a shortfall of carbon to drive nitrogen removal, the most cost-effective side stream technologies have been shown to be those based on anammox bacteria. The representative technologies discussed therefore are limited to those vendors that have developed reactor configurations that utilize anammox technology.

B.1 The Anammox Process

Traditional nitrogen removal is accomplished through nitrification and denitrification. Ammonia is oxidized to nitrite by the ammonia oxidizing bacteria (AOBs) and nitrite is then oxidized to nitrate. Nitrification requires oxygen. Denitrification is the biological reduction of nitrate to ultimately produce nitrogen gas. A carbon source is required as an electron donor in this process. It can either be present in the influent wastewater or added as an external carbon source such as methanol. A schematic of the traditional nitrogen removal process is given in Figure B-1.

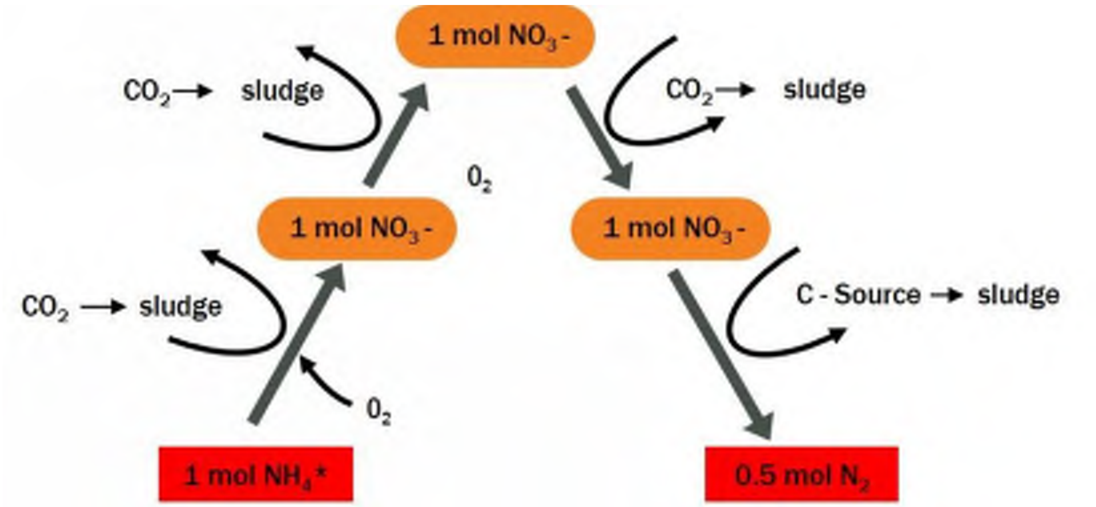

Figure B-1. Traditional nitrogen removal process

The anammox process short-circuits the traditional pathway of nitrification and denitrification reducing the amount of oxygen required by 40% and eliminating the need for carbon. Figure B-2 illustrates the anammox process schematic.

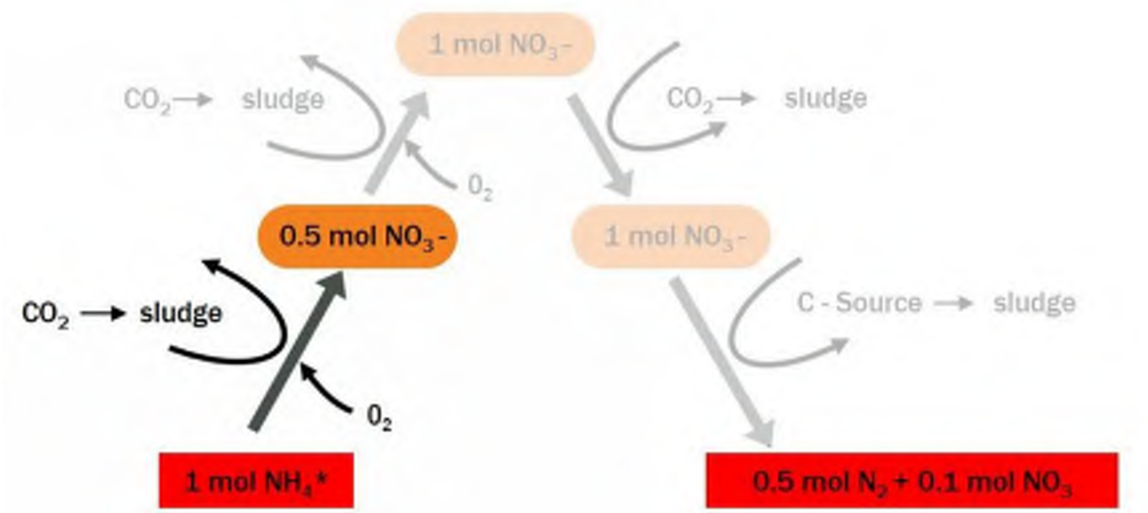

Figure B-2. Deammonification nitrogen removal process

B.2 Demon/Condea™ Process

The Demon process is the most widely sold system using anammox bacteria. The organisms grow in a granular form and because of their size and density, they settle very quickly compared to activated sludge floc. Both anammox and AOBs are maintained in the granules. The fast settling granules benefit a sequencing batch reactor configuration. The granules are separated from unwanted heterotrophic organisms through settling and decantation. Enrichment of granules within the reactor is achieved with hydrocyclones. There are 65 Demon reactors installed worldwide, with the largest processing 27,000 lb nitrogen/day. In comparison, the CVWRF will process approximately 5,000 lb nitrogen/day. Recent business developments have caused the vendor, World Water Works, Inc. to alter the reactor configuration to a continuous flow system, known as Condea™. There is one full-scale Condea™ process in operation. The Condea™ system is similar to the Demon process, albeit that a more positive method of solids separation is provided via an integral settling chamber and a microscreen is used to enrich the anammox bacteria in place of a hydrocyclone as shown in Figure B-3. As with the Demon process, the reactor is intermittently mixed and intermittently aerated.

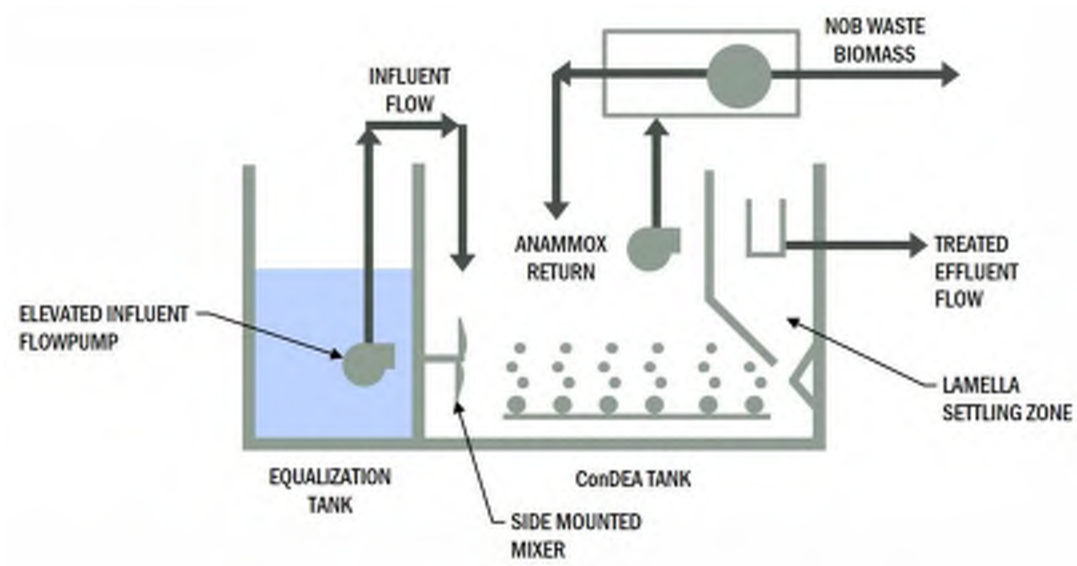

Figure B-3. CondeaTM process flow schematic

B.3 Anita™Mox Process

Marketed by Veolia/Kruger, the Anita™Mox process uses anammox bacteria as in the Demon process but arranged in a fixed film configuration. Biofilms grow on plastic media (Figure B-4) in a reactor similar to a moving bed biofilm bioreactor (MBBR) (Figure B-5). The biofilm makes the process more resilient because solids settleability is not a constraint and it can operate at higher dissolved oxygen (DO) and nitrite concentrations than the Demon/Condea™ process. The plastic carriers are kept in suspension by continuous aeration and mixing. The continuous aeration and mixing increases power consumption compared to the Demon/Condea™ process. Coarse bubble aerators are used but oxygen transfer is not impeded because the shearing action of the carriers breaks up the coarse bubbles into fine bubbles. Coarse screens are required to prevent loss of the carriers to the effluent overflow.

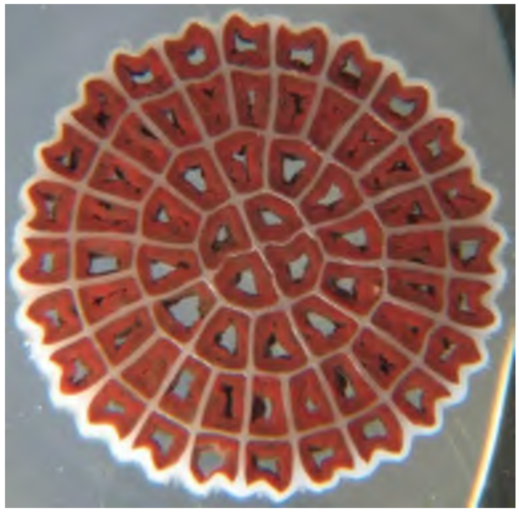

Figure B-4. Biofilm covered plastic carrier

Figure B-5. MBBR reactor configuration

This process has been successfully piloted at the Denver Metro WWTP and is under design for installation at the Metropolitan Water Reclamation District of Greater Chicago's Stickney WWTP and the South Durham, North Carolina WRF. There are six full-scale plants in operation in Sweden, Germany and China and one US installation at the Hampton Roads Sanitation District, Virginia.

B.4 AnammoPAQ™ Process

Marketed by Ovivo, the AnammoPAQ™ process uses anammox bacteria in a granular mode that are kept in suspension by continuous aeration that maintains a DO concentration of approximately 5 mg/L. An internal lamella separator provides solids separation and granule retention as shown in Figure B-6.

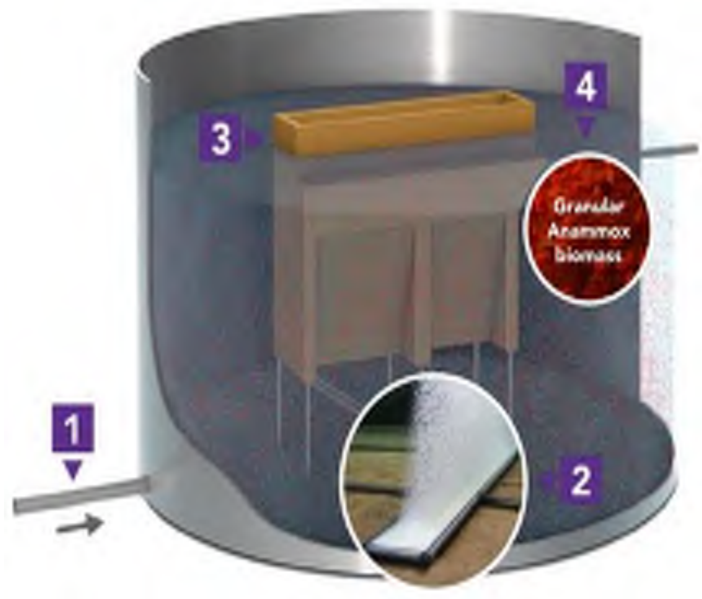

Figure B-6. Cross-section through AnammoPAQTM reactor

Approximately 45 full-scale AnammoPAQ™ reactors are in use worldwide, most being for industrial applications, with the largest processing 25,000 lb nitrogen/day. No installations are located in the US.

B.5 Comparison of Biological Processes

Table B-4 provides a comparison of the major features of the three most commercial anammox processes.

Table B-4. Comparison of Anammox Processes

	ConDeA/Demon	ANITA mox	Anammo PAQ
Flow	Continuous	Continuous	Continuous
Aeration	Intermittent	Continuous	Continuous
Anammox bacteria form	Granules	Biofilm on media	Granules
Method of retaining Anammox bacteria	Internal clarifier + microscreen retention	Media retention screens (coarse screens)	Lamella plate settler inside reactor
Worldwide prevalence	1 installation of ConDEA >65 installations of DEMON Mostly municipal	Approximately 10 installations (overseas) Mostly municipal	>45 installations Mostly industrial Mostly in China

B.6 Ammonia Stripping and Absorption

This technology has been used by industry to recover ammonia from ammonia-rich streams for nearly 100 years. The technology was installed in the South Tahoe, Nevada WWTP and Water Factory 21, California in the 1970s as part of the US EPA Advanced Wastewater Treatment Technology Program. The lime scaling problems experienced at these plants caused the technology to be abandoned in the US. However, many facilities exist in Germany.

The process consists of two column reactors. The first column is packed with loose fill plastic media. The side stream is dosed with caustic to raise its pH to approximately 10 allowing ammonia to be stripped to the air. The side stream is also heated to approximately 150°F to increase stripping efficiency. It enters at the base of the column and rises counter-current to a stream of air (Figure 7). Once stripped, the ammonia-rich air stream is directed to a second column and passes counter-current through a stream of sulfuric acid that is sprayed from the top of the tower (Figure B-7). The acid converts the ammonia to ammonium sulfate liquid, which can be sold as a fertilizer by-product.

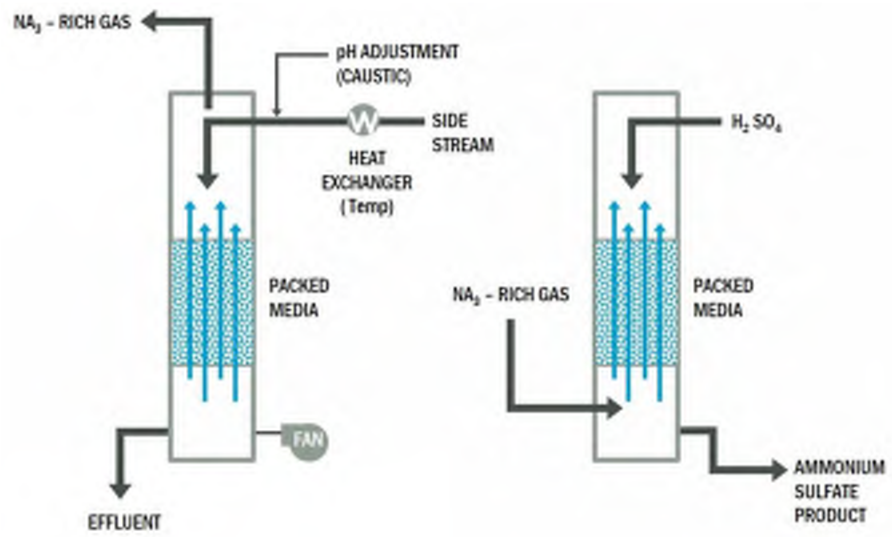

Figure B-7. Stripping (LHS) and absorption (RHS) of ammonia in a two-stage column reactor

B.7 Comparison of Biological and Physical-Chemical Side Stream Processes for Nitrogen Removal

The biological and physical-chemical processes of nitrogen removal from side streams are compared in Figure B-8. Shown are the major inputs and outputs of the two processes.

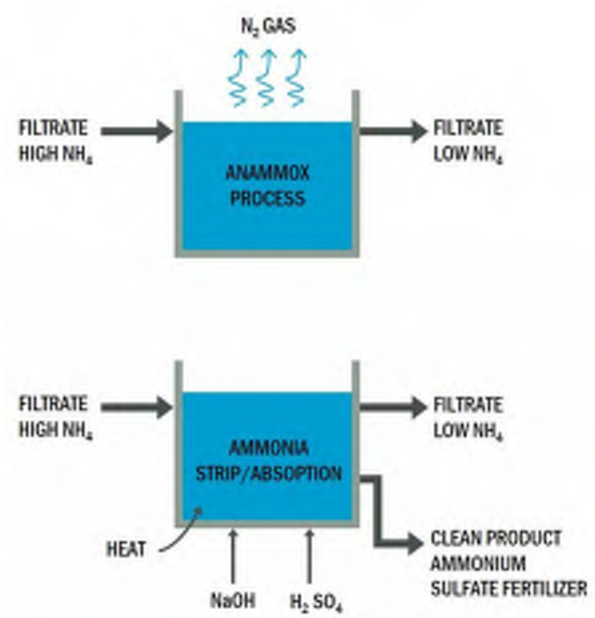

Figure B-8. Comparison of anammox biological side stream nitrogen removal process with ammonia stripping/absorption

The mechanism by which nitrogen is removed differs between the two groups of processes. In the case of the anammox processes, nitrogen is removed as nitrogen gas. For ammonia stripping/absorption, nitrogen is removed as ammonium sulfate. The major process requirements for anammox are aeration, whereas for ammonia stripping/absorption, the major process requirements are caustic and sulfuric acid addition and heating.

Sidestream Phosphorus Removal Processes

Many side stream phosphorous (P) removal processes have been developed over the past decade. Currently, there are more than 30 different technologies available for recovering P depending upon whether P is removed from the liquid stream (filtrate), the solids stream or from an ash following sludge incineration. Figure B-9 illustrates the range of technologies that are being pursued in Europe.

At present, there are less than ten that are commercially available. Because struvite manifests itself as a nuisance precipitant in the digester and solids dewatering stream, most technologies have focused on the controlled precipitation of struvite in a manner that will allow recovery as a saleable product. Struvite forms when the molar ratio of magnesium, ammonium and phosphorus is approximately 1:1:1 and normally under slightly alkaline pH values, according to the following simplified equation:

$$NH_3 + H_3PO_4 + Mg(OH)_2 + 4\ H_2O \rightarrow MgNH_4PO_4.6H_2O$$

Crystals of struvite will form when the concentrations of the three components exceed the solubility limit and have a suitable location to grow. The commercially available systems seek to control the formation and size of the crystals through pH control, either through caustic addition or stripping of carbon dioxide and through the addition of a magnesium salt to achieve the correct molar ratio, usually in a fluidized bed reactor configuration.

The technologies identified in Figure B-9 were reviewed to determine their viability for the CVWRF application. Table B-5 summarizes the most commonly reported of the commercially available technologies. Note is made of the country of origin of the technology, the number of full-scale reactors in operation in the U.S. and in other countries within the municipal wastewater treatment sector as well as their application in industrial sectors.

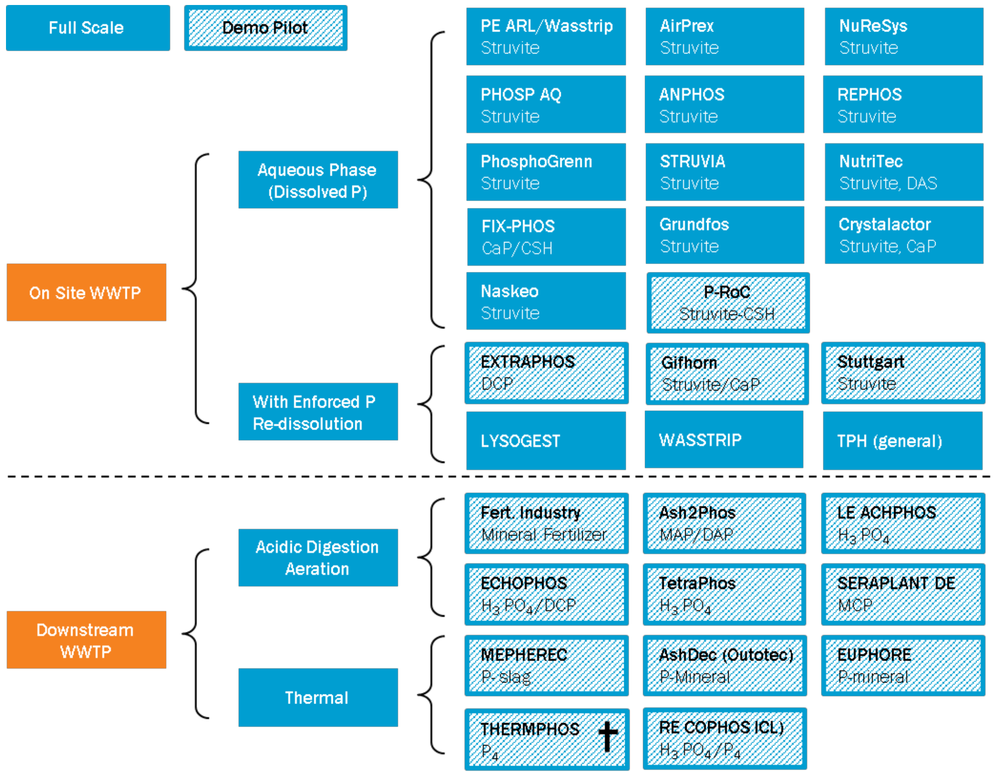

Figure B-9. Range of Phosphorus Removal Technologies Applied in Europe (Kabbe & Kraus, 2017)

Table B-5. Commercially Viable Side Stream Phosphorus Removal Processes

Technology	Source	No. of Municipal Full-Scale Facilities (U.S./Other Countries)	No. of Full-Scale Industrial Facilities	Total No. of Full-Scale Facilities
Airprex	Germany	2[1]/8	0	10
Crystalactor	Netherlands	0	60	60[2]
Multi-Form Harvest	USA	4/0	0	4
Ostara-Pearl	Canada	12/4	0	16[3]
NuReSys	Belgium	0/6	3	6[4]
Phospaq	Netherlands	0/3	2	3[5]
Phosnix	Japan	0/2	0	2
Calprex	Germany	0	0	0[6]

[1]Although constructed and scheduled for startup this year, these plants have not started up yet because of delays in the construction of the Cambi Process at Medina OH (Airprex capacity: 74,000 gal/day digested sludge) and the anaerobic digester at Savage MD (Airprex capacity: 208,000 gal/day digested sludge), respectively.
[2]RoyalHaskoningDHV of the Netherlands designs these fluidized bed crystallizers for industries that require softening, demineralization, fluoride recovery, heavy metal removal, phosphate recovery and brine management. They do not service the municipal market.
[3]12 of the 16 systems sold have the supplementary WASSTRIP technology or intend to install it in the future.
[4]NuReSys is being marketed by Schwing-Bioset in the U.S. One system has been sold in the U.S. recently (November 2018).
[5]Phospaq is being marketed by Ovivo in the U.S. No systems have been sold in the U.S. to date.
[6]Calprex is being marketed by CNP-Tec (AirPrex) in the U.S. No systems are available in the U.S. or Europe.

Technical Memorandum 3

Energy System Evaluation

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Technical Memorandum

Prepared for: City of Portsmouth

Project Title: Digester Feasibility Study

Project No.: 152936

Technical Memorandum 3

Subject: Energy Systems Evaluation

Date: May 20, 2019

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List of Abbreviations

°F	degrees Fahrenheit
Btu	British thermal unit(s)
CFR	Cod of Federal Regulations
CHP	combined heat and power
City	City of Portsmouth
RBPF	Regional Biosolids Processing Facility.
DG	digester gas
EPA	Environmental Protection Agency
FOG	fats, oil, and grease
hr	hour(s)
HVAC	heating, ventilation, and air conditioning
IC	internal combustion
kW	kilowatt
M	million
mgd	million gallons per day
MMBtu	million British thermal unit(s)
MW	megawatt(s)
NEM	net electrical metering
NPDES	National Pollutant Discharge System
NPV	Net present value
O&M	operations and maintenance
psig	pounds per square inch gage
scfm	standard cubic feet per minute
THP	thermal hydrolysis process
TM	Technical Memorandum
VOC	volatile organic compound
WW	wastewater
WWTF	wastewater treatment plant

Section 1: Introduction

This Technical Memorandum (TM) 3 describes the Energy Systems Evaluation for the digester gas combined heat and power (CHP) energy recovery system for the Regional Biosolids Processing Facility (RBPF). The City is evaluating the construction of a RBPF to provide stabilization of wastewater solids through anaerobic digestion, which will generate renewable biogas that can be used for electricity and useful heat production in a CHP system. The Energy Systems Evaluation was conducted in the context of satisfying the following project drivers:

- Install energy recovery equipment to avoid wasting biogas generated on site;
- Coordinate CHP system implementation with other required ancillary system installation;
- Minimize potential odor or noise impacts from any new CHP system to surrounding properties;
- Minimize potential operations and maintenance (O&M) impacts;
- Provide revenue to develop an economically viable project based on net present value (NPV)

Section 2: Basis of Evaluation

This section describes the basis of evaluation for the cogeneration alternatives, which includes an estimate of digester gas production, RBPF heating requirements, gas treatment assumptions, and the NPV assumptions.

2.1 Digester Gas Production

The evaluation is based on two alternatives, depending on the quantity of biosolids and import organics that will be sent to the digesters. Alternative 1 assumes municipal wastewater solids from Peirce Island and Pease Wastewater Treatment Facilities (WWTFs) are digested and Alternative 2 assumes solids from Peirce Island and Pease WWTFs are co-digested with import materials, including outside cake, fats, oil, and grease (FOG), and food waste.

Design data must be calculated based on projected solids loading and anticipated digester performance, since site specific operational data is not available. The solids loading estimates, parameters, and assumptions used to determine the digester gas projections are described in greater detail in TM 1, Flows and Loads. The basis of evaluation for the two solids loading alternatives in this evaluation is presented in Table 2-1. It is assumed that the digester gas will have a lower heating value of 560 British thermal units per cubic foot, which is a typical value for biogas.

Table 2-1. Digester Gas Production Estimates: Two Alternatives

Alternative	2020 Average Gas Production, scfm	2040 Average Gas Production, scfm	Comments
1. Peirce and Pease WW Solids	38	85	Only WW municipal solids; no import
2. Peirce and Pease WW Solids + Import	193	297	Assumes outside cake, THP, and FOG imported for co-digestion

2.2 Electrical Demand

The load requirements of the new RBPF will be used to determine the electrical savings from the cogeneration system. The electrical demand is related to the quantity of biosolids and import materials processed at the RBPF and the methodology for estimating these demands is described in detail in TM 5 and summarized in Table 2-2. Alternatives that produce more power than is required to run the RBPF are assumed to export power through a net electrical metering (NEM) agreement.

Table 2-2. Electrical Demand Estimates: Two Alternatives[1]

Alternative	Average Electrical Demand, kW	Comments
1. Peirce and Pease WW Solids	292	Only WW municipal solids; no import
2. Peirce and Pease WW Solids + Import	546	Assumes outside cake, THP, and FOG imported for co-digestion

1. Not including cogeneration parasitic demands, which account for 6 to 10 percent of the system output.

2.3 Digester Heating

The RBPF is first and foremost a biosolids treatment facility; therefore, the needs of the treatment process must be satisfied. The heating demands of the digesters must be met by each alternative either through the use of boilers or cogeneration heat recovery. Heat demand is based on the heating of raw sludge flows with an allowance for heat loss from the digester shell. Table 2-3 shows assumptions that are incorporated into the heat demand calculation for each alternative and the resulting heat demands for Alternatives 1 and 2.

Table 2-3. Digester Heating Demand

Parameter	Unit	Value
Raw sludge temperature, typical temperature	°F	55
Digester operating temperature	°F	98
Heat loss through digester shell	Percent of total	15
Alt 1 heat required, annual average	MMBtu/hr	0.40
Alt 2 heat required, annual average	MMBtu/hr	1.40

2.4 Digester Gas Treatment

All potential cogeneration technologies considered require digester gas treatment; consequently, each alternative includes a digester gas conditioning system to remove hydrogen sulfide, siloxanes, and moisture. The cost of the digester gas conditioning system varies for each alternative depending on the quality of treated gas and the operating pressure required. Typically, higher operating pressures (for microturbines) are expected to increase parasitic loads associated with electrical compression. Section 3 includes a more detailed description of the gas conditioning system.

2.5 Net Present Value Assumptions

The assumptions for the solids loadings to the RBPF are described in greater detail in TM 1. This analysis assumes constant 2040 plant loadings and digester gas production through the 20-year evaluation. The NPV analysis as described further in TM 4, Financial Model Evaluation, treats growth as follows:

- The estimated performance model and O&M costs were based on projected 2040 plant loadings. If solids production significantly increases, the gas treatment train and cogeneration systems would need to increase in capacity.
- Where alternatives require new facilities and/or equipment, they were sized (and estimated) based on projected 2040 solids loadings and resulting digester gas flows.
- Capital cost estimates are equivalent to a Class V (+50/- 30 percent) and are relative to one another. These capital costs should not be used for project budgeting purposes. The capital costs are provided for the purpose of evaluating alternatives and should be vetted as part of a more in-depth cost estimate as the project scope is developed.
- NPV was calculated over 20 years with a 2.5 percent discount rate and a 2.0 percent escalation rate. TM 4 includes a summary of all assumptions used in developing the NPV model.

Section 3: Biogas Technologies

Table 3-1 lists the alternatives evaluated in this TM and a description of each alternative's major process components. A brief review and comparison of alternative technologies for digester gas conditioning and cogeneration are provided in this section, beginning with the gas conditioning technologies that are common to all alternatives. Each alternative was evaluated with estimated 2040 digester gas production projections.

Table 3-1. Biogas Utilization Alternatives

Alternative	Description/Major Components
1-CHP – Peirce and Pease Solids + Mesophilic	• All DG is sent to 355 kW engine to produce heat and power • This option produces sufficient heat for the digesters; propane is not required in the boiler
2-CHP – Peirce and Pease Solids + Outside Cake + THP + FOG + Mesophilic	• All DG sent to 788 kW engine to produce heat and power up to RBPF demand; excess DG is flared • This option produces sufficient heat for the digesters; propane is not required in the boiler

3.1 Biogas Conditioning

Biogas typically contains methane, carbon dioxide, water vapor, hydrogen sulfide, ammonia, nitrogen, volatile organic compounds (VOCs), siloxanes, and trace amounts of other components. Some of these compounds can harm a CHP system and must be removed before combustion. For example, hydrogen sulfide can cause engine corrosion, and siloxanes oxidize during combustion to form silica particles that can damage an engine or microturbine. These contaminants can reduce the overall CHP efficiency and increase O&M costs if not removed; hence, most new CHP systems require upstream gas conditioning. Additionally, the combustion of some compounds, such as hydrogen sulfide, produces harmful and regulated air pollutants. Figure 3-1 presents a process flow schematic for a conventional digester gas conditioning system and Figure 3-2 shows an installation at Santa Rosa Laguna WWTF.

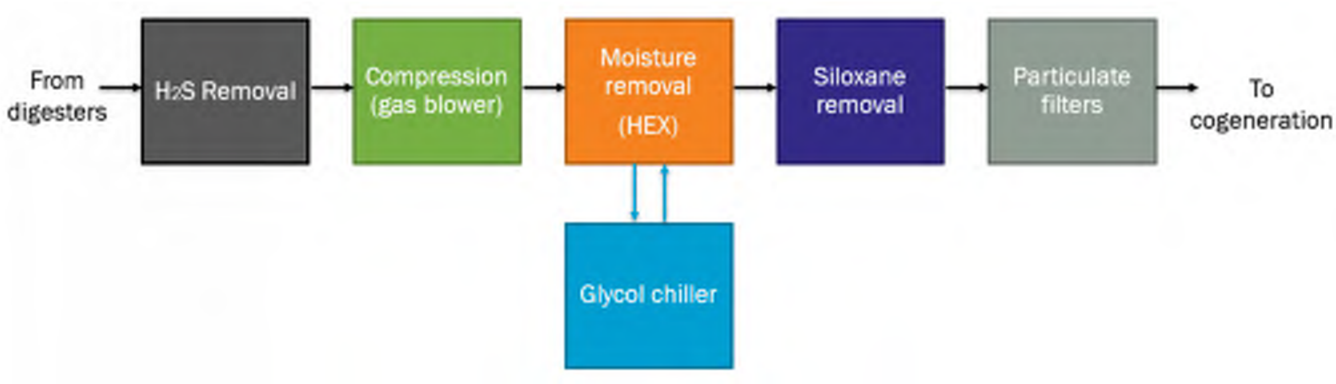

Figure 3-1. Process flow diagram for a typical gas conditioning system

Configurations may vary, depending on equipment suppliers and treatment needs.

Figure 3-2. Gas conditioning system at the Santa Rosa Laguna Treatment Plant, including hydrogen sulfide removal vessels, siloxane removal vessels, and chillers

Gas treatment system design is driven by raw biogas flowrate, raw biogas quality, and post-treatment requirements. Post-treatment requirements are dependent on fuel end use (internal combustion [IC] engines, IC engines combined with exhaust treatment, and microturbines); however, all options require low hydrogen sulfide and siloxane concentrations and minimal water content. Since the City does not have existing digester gas quality information available, the equipment sizing, selection, and O&M costs will assume future digester gas is of typical WWTF quality.

It should also be noted that modifications to upstream biogas-producing systems may alter raw biogas quality. For example, additional high strength waste quantities may increase hydrogen sulfide and ammonia concentrations and thermal hydrolysis processing systems can result in significant concentrations of ammonia in the biogas.

3.1.1 Hydrogen Sulfide Removal

Hydrogen sulfide and other sulfides are typically removed from warm, moist DG using packed-bed vessels to prevent corrosion, odors and reduce sulfur oxide emissions from combustion sources. The packing can be iron sponges, which consist of iron-oxide-impregnated wood chips or a specialized granular iron-impregnated media such as SulfaTreat. Iron sponges typically have the lowest life-cycle costs but are more difficult to remove from the vessels than a granular media as the media tends to "cement" together over time. Figure 3-3 shows a comparison between iron sponge and granular iron hydroxide media.

Figure 3-3. Iron sponge media (left) and granular iron hydroxide media (right)

At least two hydrogen sulfide removal vessels are typically installed to allow operation during media replacement or regeneration. This evaluation will assume two conventional vessels are included in the capital cost and footprint, but future digester gas sampling will be required to determine the best technology and media for the RBPF.

Other hydrogen sulfide removal technologies exist for installations with high hydrogen sulfide in the digester gas and higher digester gas flows. These technologies include:

- Aerobic biotrickling filters;
- Ferric chloride dosing at the digesters.

3.1.2 Compression and Moisture Removal

The digester gas must be boosted in pressure to overcome the pressure losses of the gas treatment system and generally to supply enough pressure for use in CHP. The digester gas pressure is boosted by a blower or compressor, which also adds heat to the digester gas.

Moisture is removed from the biogas to help prevent CHP damage from condensing water droplets. Following compression, water is removed by cooling the digester gas to approximately 35 degrees Fahrenheit (°F) in a heat exchanger, forcing moisture to condense. Once the gas dew point is lowered causing condensate to drop out of the gas, the cold gas is reheated to around 80°F using the incoming hot blower or compressor discharge flow. This reheating improves the effectiveness of the downstream siloxane removal media and reduces the relative humidity of the digester gas. An air-cooled glycol chiller is typically supplied to provide cooling to the heat exchanger in the form of a cold water and ethylene glycol solution. The percentage of ethylene glycol in the solution is dependent on the project location and prevents the chilled water from freezing in the pipes.

3.1.3 Siloxane Removal

Digester gas contains various species of siloxanes commonly found in household and personal-care products such as deodorants and lotions. When digester gas and siloxanes are combusted in a CHP engine, the siloxanes oxidize to form silica particles that can build up and cause significant damage to CHP engine components and exhaust catalysts.

The most common siloxane removal method is adsorption via activated carbon media, shown in Figure 3-4, which has microscopic pore spaces and a resulting high surface area to particle size ratio. This high ratio makes activated carbon an effective media for adsorbing molecular contaminants. The media typically becomes exhausted after 3 to 6 months and must be replaced regularly, incurring additional O&M costs. Like hydrogen sulfide removal, at least two vessels are recommended so that one vessel can be taken offline during media removal or maintenance. Multiple vessels may be placed in series to treat biogas with high siloxane concentrations and avoid siloxane breakthrough that can harm downstream equipment. Particulate filters are usually installed downstream to capture any activated carbon particles that become suspended in the biogas.

Figure 3-4. Activated carbon media

3.2 CHP Prime Mover Selection

A demonstrated method for energy recovery from biogas is the use of cogeneration systems to generate on-site electrical power and useful thermal energy, allowing for overall combined electrical and thermal efficiencies of up to 85 percent. Common prime movers for small to medium cogeneration systems include IC engines and microturbines, discussed in this subsection. Figure 3-5 shows a general process flow diagram of CHP systems.

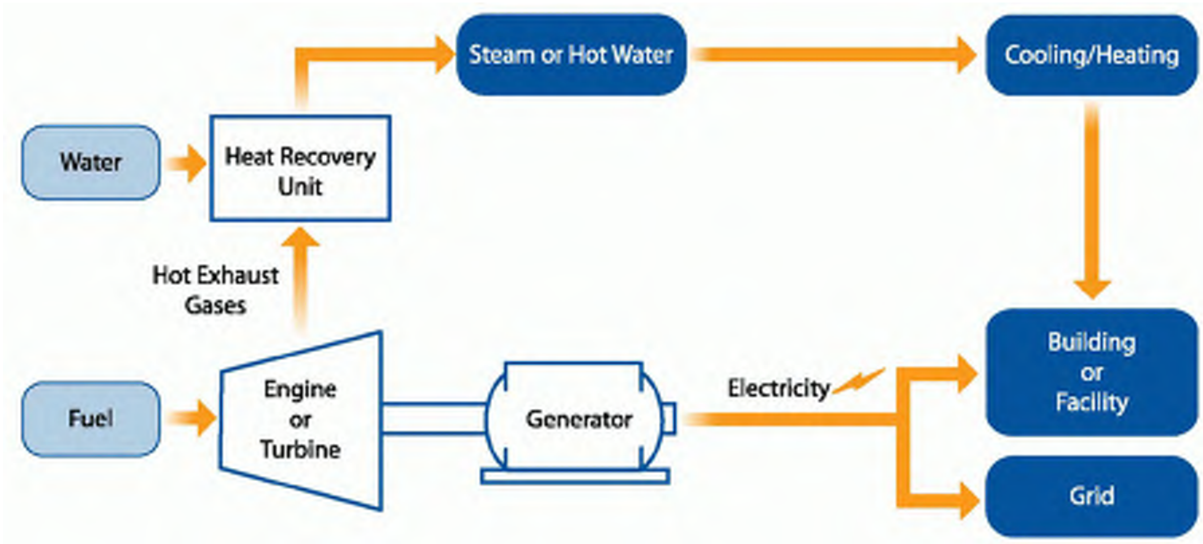

Figure 3-5. Combustion turbine or engine CHP system

Source: epa.gov

3.2.1 IC Engines

Biogas-fired IC engines for electric generation can be supplied at a range of output capacities for very small or very large digester gas flows and are widely used at WWTFs for their competitive fuel economy, durability, reliability, compact foot print, and lower capital investment. With overall combined electrical and thermal efficiencies of up to 85 percent, IC engines make effective use of digester. They have also been installed with multiple units to provide for a larger plant capacity while providing good turndown (see Figure 3-6).

Figure 3-6. IC engine cogeneration system at Annacis Island WWTF in Vancouver, British Columbia

Preliminary Engine Sizing

To determine preliminary engine sizes, the total available digester gas energy was converted to an electrical power output assuming an engine electrical efficiency of 36 percent. Based on the estimated electrical power output, engine sizes were selected with the following considerations in mind:

- Engine would be partially loaded at average conditions to provide capacity for high-production conditions and accommodate future digester gas production (see Table 3-2);
- Multiple suppliers are available to provide selected engine size to allow for competitive bidding;
- Allow for one engine to utilize digester gas available anticipated at startup;
- Select engine to produce power up to new RBPF demand; assume excess digester gas is flared and additional power is not exported.

Table 3-2. Proposed Engine Fuel Consumption

Alternative	Proposed Engine Size (kW)	Output to RBPF Demand (kW)	Percent of Digester Gas Utilized (percent)	Load Operation (percent)
Alt 1 – CHP	1 at 335 kW	395	61	88
Alt 2 – CHP	1 at 788 kW	693	61	88

3.2.2 Microturbines

Microturbines are small combustion turbines that generate heat and electricity. Microturbines are composed of a few key components and produce heat and power through the following steps:

- A compressor draws air into the engine, pressurizes it, and feeds it to the combustion chamber;
- In the combustion system, fuel (digester gas) is injected into the combustion chamber where it is mixed with air. The mixture is combusted, which produces a high temperature, high pressure gas that enters and expands in the turbine section;
- Hot combustion gas expands through the turbine, causing the rotating blades to spin. These rotating blades drive the compressor to draw more pressurized air into the combustion system and spin a generator to produce electricity;
- Hot exhaust gas contains thermal energy that can be beneficially used in the plant.

While microturbines have a lower electrical efficiency, they also have the potential for more heat recovery and typically see much higher uptimes than IC engines. Packaged microturbine units are available in capacities ranging from 30 to 333 kilowatts (kW) per unit. Microturbines are a compact, easily scalable, low-emission technology for utilizing biogas. Microturbines are extremely sensitive to siloxanes and require gas conditioning to remove sulfides, moisture, and siloxanes and require compression up to 80 pounds per square inch gage (psig). One of the disadvantages, in comparison to IC engines, is a lower electrical efficiency; microturbines have an efficiency of 29 to 32 percent while IC engines have an efficiency of 30 to 42 percent. Figure 3-7 shows a microturbine package installation with capability of producing 1,000 kW.

Figure 3-7. Capstone C1000, 1000 kW microturbine package with integrated exhaust manifold

Sheboygen Regional WWTF, Wisconsin.

Microturbines have two significant disadvantages:

- There are only two main microturbine manufacturers in the United States, Capstone and FlexEnergy. FlexEnergy purchased Ingersoll Rand's microturbine business and has few wastewater installations. Neither company has significant financial resources, and there is a risk that long-term product support may not be available. Capstone is the only microturbine manufacturer that provides a unit suitable for the RBPF's anticipated gas production, and this may be a potential risk for securing long-term parts and support. The limited service support must be considered if this technology is ultimately selected;
- Microturbines are extremely sensitive to siloxanes and require gas conditioning to remove sulfides, moisture, and siloxanes and require compression up to 80 psig. Due to the small passageway within the recuperator and large surface area of siloxanes, siloxanes must be monitored frequently (i.e., monthly) to prevent siloxanes from entering the recuperator. Siloxane tests are conducted by sending samples to a lab and cost approximately $250 per sample.

Although engines are the more common cogeneration technology used at WWTFs, and usage of the newer microturbine technology is more limited, several WWTFs in the United States operate Capstone microturbines including Janesville, Wisconsin; Sheboygan, Wisconsin; Durango, Colorado; Persigo, Colorado; Ithaca, New York; and Santa Margarita, California—all of which have reported successful operation with the 65 kW units. The issue of long-term microturbine support raises serious concerns and are therefore not recommended for this application.

3.2.3 Comparison of Cogeneration Technologies

The relatively small quantities of digester gas that will be available at the RBPF is suitable for IC engines or microturbines. Table 3-3 provides a brief overview of the key differences between microturbines and IC engines as discussed in this section.

Table 3-3. Comparison Between Microturbines and Engines		
Category	**Microturbines**	**Engines**
Capital costs	Lower in comparison to engines	Higher in comparison to microturbines; more ancillary equipment required such as a radiator, lube oil, HVAC, and inertia block; ancillary equipment requires more footprint, piping, instrumentation and controls, and electrical
Sizing	30, 65, 200, 250, and 333 kW units	60 kW to >3 MW
Electrical efficiency	28–32% (moderate)	27–34% (moderate)
Thermal efficiency	20–25% (low)	30–40% (high)
Maintenance requirements	Approximately 5% downtime for maintenance Moderate maintenance costs. Long term maintenance support from manufacturers and third parties questionable	5 to 10% downtime for maintenance Moderate to high maintenance costs
Turndown	Can tolerate some turndown (50% of full load) while maintaining high electrical efficiency	Can tolerate some turndown (70% of full load) while maintaining high electrical efficiency
Fuel requirements	Hydrogen sulfide (depending on raw digester gas properties), siloxane, and moisture removal Medium fuel gas pressure required (80 psig)	Hydrogen sulfide, siloxane, and moisture removal Low fuel gas pressure required (3 psig)
Natural gas blending	Available in manufacturer's scope of supply	Available in manufacturer's scope of supply
Noise	Fairly quiet operation	Loud operation
Permitting	Lower emissions	Moderate exhaust emissions; may require exhaust treatment, but unlikely; regulatory requirements must be evaluated
Manufacturers	Capstone or FlexEnergy (only for <250 kW units)	Cummins, Waukesha, Caterpillar, Dresser Rand, Lieberr, MTU, Jenbacher

3.2.4 Electrical Interconnection

The cogeneration system must be electrically interconnected to the RBPF's distribution system, in parallel and synchronized with the local electrical grid, per the utility's (Eversource) interconnection standard. A suitable location is required to accept the power output from the cogeneration system while not affecting power distribution to other systems. Additional protective relays (reverse-power relays) would likely be required at the main circuit breaker at the front end of the WWTF to meet the installation requirements of the electrical utility.

Eversource provides guidelines for electrical interconnection in their *Standards for Interconnection of Distributed Generation* (2018) guidance document. For large generators greater than 100 kW, the facility must contact Eversource for site-specific interconnection requirements. The process requires submission of an interconnection application form, included as an attachment to the *Standards for Interconnection of Distributed Generation* guidance document. After the interconnection request has been filed, Eversource may conduct a feasibility study to determine any additional project requirements to ensure no adverse effects or interference will be suffered at the distribution grid.

There are two main options for the electrical interconnection, from a programmatic perspective, behind-the-meter and utility-side. The meter in this case refers to the facility meter associated with the corresponding Eversource account. The interconnection strategy selected typically depends on whether the cogeneration system will produce more electricity than is required on site, and how much revenue can be realized from exporting the excess electricity to the grid. Interconnecting behind-the-meter allows the facility to enroll in

NEM, in which a special bi-directional meter is installed to measure the flow of excess electricity back to the utility distribution system and the facility is compensated at near-retail rates. NEM is administered by the New Hampshire Public Utilities Commission as an opportunity to realize a higher revenue opportunity for electricity sale compared to selling electricity to a utility at wholesale rates or negotiating a power purchase agreement with a third party. However, there is an added capital investment for the more specialized interconnection and bi-directional meter compared to an interconnection on the utility distribution circuit.

At this stage in the evaluation, it has been assumed that the cogeneration system will be sized to meet the on-site power demands and will not include NEM for export. The cogeneration system sizing will depend on where the RBPF will be located; if located near the existing Pease WWTF, the system should be sized to meet the power demands of the WWTF, thereby impacting the lifecycle costs. Based on similar projects in California, the capital cost of NEM export can range from $0.5 to $2 million, depending on the facility size and utility interconnection requirements. Because of the complexities of exporting power in addition to the reduced rate at which power is sold (typically about 50 percent of what the WWTF utility pays per kW hour), few facilities export power. However, it can be feasible for larger agencies, such as East Bay Municipal Utilities District in California, to export power to a nearby user when excess power is generated. These are more detailed arrangements that should be considered and developed once the RBPF size and location are determined.

3.2.5 Emissions and Air Permitting Considerations

The RBPF would be located along the New Hampshire Seacoast, with few residential units and commercial buildings adjacent to the plant fence line. Emission limits will depend on whether the cogeneration system requires a New Hampshire state permit or if it can operate under the federal emission standards. System classification and performance testing under the federal standards are provided under the National Emission Standard for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines, 40 Code of Federal Regulations (CFR) 63, Subpart ZZZZ. Compliance monitoring activities for the system will likely include an initial emissions performance test, periodic (semiannual) performance testing, and semiannual compliance reports. Specific emissions criteria limits, such nitrogen dioxide, carbon monoxide, and VOCs are regulated under New Source Performance Standards – Standards for Performance or Stationary Spark Ignition Internal Combustion Engines 40 CFR 60, Subpart JJJJ. Most commercially available cogeneration units can meet the federal emissions standards without an emission treatment system.

State operating permits are required if the cogeneration system emissions exceed a threshold or meet the criteria found in the New Hampshire Code of Administrative Rules Env-A 600 Statewide Permit System. The permit will be issued with specific emissions limits and requires payment of an annual emissions-based fee multiplied by the total annual emissions.

Based on recent permitting of similar projects in other parts of the country, it is likely that an oxidation catalyst will be required on the engine exhaust to control carbon monoxide to comply with Best Available Control Technology (BACT) air permit requirements. To avoid plating the catalyst, siloxane removal systems must be monitored carefully between the lead and lag vessels so that any breakthrough can be detected before it has a chance to reach the engine. Siloxane breakthrough is determined through a grab sample and shipped to a remote laboratory for analysis; this sampling process can take up to a week. It is uncertain if intensive engine exhaust treatment such as selective catalytic reduction or an oxidation catalyst will be required; exhaust treatment systems will add capital costs and potentially increase ongoing O&M costs.

Because microturbines produce low emissions in comparison to an IC engine, they may not require an air permit or an air permit may be less difficult to obtain. If the RBPF progresses beyond this analysis, it is recommended the City engage with New Hampshire Department of Environmental Services to determine permitting requirements that may impact the energy recovery alternative.

3.3 CHP System O&M

The cost for scheduled maintenance of the CHP system was accounted for separately on a dollar per kW hour (kWh) basis given BC experience with CHP provider service contracts, the details of which are provided below.

3.3.1 IC Engines: Maintenance Costs

The O&M costs for the IC engine alternatives are based on industry experience and vendor data. The engine-generator costs cover routine maintenance such as oil changes and filter replacements and major events such as top- and bottom-end overhauls. The gas treatment O&M includes costs for H_2S and siloxane removal media replacement, gas compression, and moisture removal. The O&M costs for the IC engine alternatives are shown in Table 3-5. Note that the engine and gas treatment operating costs are expressed on a per kWh basis to reflect the run time and wear on the system.

Table 3-5. IC Engine and Gas Treatment Operating Cost Assumptions

Criterion	Value
Engine-generator O&M, $/kWh [a]	0.025
Blower and chiller power, percent of produced power [b]	6%
Gas treatment maintenance, $/kWh [c]	0.015
Labor: gas treatment (FTE)	0.1
Labor: engine-generator (FTE)	0.25
Engine availability (uptime), %	90%

a. *Based on gross output of engine-generator. Value based on industry experience and service plans for similarly sized engines.*

b. *Assumes compression to 5 psig.*

c. *Includes media replacement purchase, shipping, labor, and disposal.*

d. *These are rough estimates based on experience. The ultimate values may vary a little or moderately depending on regulatory impacts, inflation or local impacts.*

3.3.2 Revenue

Electricity generated from an onsite CHP system is typically used to supply electricity to meet the power demand at the WWTF, while electricity generated in excess of the plant's demand can be exported to the distribution grid. The core benefit of offsetting power consumption onsite is that the WWTF electricity bill is reduced by the electricity generation multiplied by the total per-kWh charges paid by the plant, accounting for distribution, transmission, standard cost recovery, system benefits, electricity consumption tax, and energy service charges.

As discussed above, the revenue generated from exporting excess electricity to the distribution grid is determined based on whether a facility registers under a NEM agreement, becomes a qualifying facility and sells electrify at market rates, or negotiates a power purchase agreement. However, all electricity exporting alternatives incur additional capital investment for the bi-directional interconnection and do not sell electricity back at the full per-kWh charge paid on the electricity bill. As discussed above, CHP systems at WWTFs do not typically sell excess electricity due to the considerable onsite demand and additional cost associated with the interconnection arrangement, and it was assumed that this system would also be sized to offset onsite power demand without selling excess electricity. However, it is recommended that if the project and scope definition advances this be further evaluated in a more detailed study.

Heat from the CHP system is similarly assumed to offset the propane that would be required to generate the process heating for anaerobic digestion in hot water boilers on an average annual average basis.

3.3.2.1 Energy credits

New Hampshire's Renewable Portfolio Standard (RPS) statute, *RSA 362-F*, requires each electricity provider serving New Hampshire to meet customer load by purchasing or acquiring certificates representing generation from renewable energy based on total megawatt-hours supplied. RPS requires that all electric service providers serving New Hampshire customers satisfy a percentage of their electric retail sales load with renewable energy certificates (RECs), where each REC is created from one megawatt hour (MWh) of electric generation that has been fueled by qualified renewable sources. A REC may be purchased through the established regional trading platform at the New England Power Pool Generation Information System (NEPOOL-GIS) or created through self-generation. Compliance began in 2008 with an obligation for each electric provider to obtain 4% of its load (or have the commensurate number of RECs). The obligation increases to 25.2% by 2025.

The RBPF would be eligible to sell RECs for the power and thermal energy produced from a CHP system. The certificates created from eligible renewable energy generation are sold on this regional market, and are retired throughout New England. The value of a REC can fluctuate given shifting market conditions, specifically: electricity retail sales load, number of RECs available from certified renewable sources, legislative changes to RPS obligation requirements, alternative compliance rates (ACP) (i.e. effective celling) in New Hampshire and regionally, and the mix of REC and ACP payments made by electricity providers.

As a conservative measure, the value of the RECs assumed for this study assumed a value of approximately half of the ceiling value (ACP) on the current market. This is consistent with projections from the New Hampshire Public Utilities Commission 2018 Review of the Renewable Portfolio Standard. The 2018 Review compared the projected ability of the state to meet the RPS requirements and generated an assessment of market conditions and future trends. If legislation is enacted in the future to increase the demand for RECs, then the value could rise accordingly, generating greater revenue for the City. The values assumed in this study are provided below in Table 3-6.

Table 3-6. New England REC Value Projections

Criterion	Value
Class I Electricity	$22.50 per MWh (REC)
Class I Thermal	$12.50 per MWh (REC)

References

Eversource, *Standards for Interconnection of Distributed Generation*, 2018 (https://www.eversource.com/content/docs/default-source/rates-tariffs/55-tariff-ma.pdf?sfvrsn=8582c462_6).

New Hampshire Public Utilities Commission, *Renewable Portfolio Standard 2018 Review*, 2018 (http://www.puc.state.nh.us/20181101-RPS-Review-2018-FINAL-REPORT-2018-11-01.pdf)

University of New Hampshire Sustainability Institute, New Hampshire Renewable Portfolio Standard, 2016 (http://www.puc.state.nh.us/Sustainable%20Energy/RPS/NH%20RPS%20Retrospective%202007-2015%20Report%20-%20FINAL.pdf)

Technical Memorandum 4

Financial Model Evaluation

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Technical Memorandum

Prepared for:

Project Title: Digester Feasibility Study

Project No.: 152936

Technical Memorandum 4

Subject: Financial Model Evaluation

Date: May 20, 2019

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List of Abbreviations

AACEI	Association for the Advancement of Cost Engineering International
CHP	combined heat and power
gal	gallon(s)
HSOW	high strength organic waste
kW	kilowatt(s)
kWh	kilowatt-hour(s)
MG	million gallon
MWh	megawatt-hour(s)
NPV	net present value
O&M	operations and maintenance
lbs	pounds
R&R	Replacement and Residual
RBPF	Regional Biosolids Processing Facility
RPS	Renewable Portfolio Standards
wt	wet ton
WWTF	wastewater treatment facility

Section 1: Introduction

This Technical Memorandum (TM) 4 describes the Financial Model Evaluation for the Regional Biosolids Processing Facility (RBPF) to be located at Pease Wastewater Treatment Facility (WWTF). The City is evaluating the construction of a RBPF to provide stabilization of wastewater solids through anaerobic digestion, which will generate biogas that can be used for renewable electricity and useful heat production in a combined heat and power (CHP) system. The results of the financial model are discussed further in the following sections.

Section 2: Solids Handling and Energy Systems Assessment

Brown and Caldwell (BC) created a custom model to combine mass and energy balances to evaluate both technical performance and operational costs for the new systems under consideration. These models were based on annual average solids loading conditions as described in TM 1 for both Scenario 1 (City sludges only) and Scenario 2 (City sludges and imported regional sludges and high strength organic waste (HSOW)). When combined with the capital investment required for each alternative, the model produces a net present value (NPV) lifecycle cost of each alternative that, when compared to the baseline process condition, determines its financial viability. For this study, it was assumed that the planning horizon for the project would be 20 years.

2.1 Model Cost Inputs

To extrapolate potential changes in operating costs under the planning alternatives, historical cost factors were used to project estimates for future conditions. Operational costs are based on actual costs incurred by the City of Portsmouth for fiscal year 2018; parameters evaluated included commodity prices as well as labor rates. Information was requested and received from operations staff for both commodity unit costs and the quantities used, which were not independently verified. Table 2-1 summarizes the various operational cost metrics used in this analysis. The model only indicates the operational costs for Pease WWTF, which are impacted by the various alternatives evaluated. Operational costs related to solids handling at Peirce Island WWTF were not included as these costs would still need to be incurred regardless of changes at Pease.

Table 2-1. Assumptions for Lifecycle Cost Analysis

Cost Element	Value in Model	Basis
Biosolids Hauling and Disposition		
Unclassified solids hauling and disposal (to landfill), (cost per wet ton)	$70	Current disposal costs provided by the City
Cost of hauling from Peirce Island to Pease (cost per wet ton)	$10	
Commodity Prices		
Cost of electricity, average usage (cost per kW-hour)	$0.101	Historic data from electricity bills (2018)
Cost of electricity, demand (cost per kW)	$13.74	Historic data from electricity bills (2018)
Dewatering polymer use, current belt filter press (pounds per ton of dry solids)	25	Assumed
Polymer cost, average (cost per pound of polymer)	$1.25	Based on historical average reported by Portsmouth staff

Table 2-1. Assumptions for Lifecycle Cost Analysis		
45 percent Potassium hydroxide solution usage (pound of solution per dry ton)	180	Provided by vendor
45 percent Potassium hydroxide solution cost (cost per pound solution)	$0.33	Provided by vendor
Operations and Maintenance		
Digester annual cleaning and maintenance	$50,000	Assumed
Dewatering annual maintenance (cost per dry ton)	$8	Based on Brown and Caldwell project experience
Cost of Engine and gas conditioning operations and maintenance (cost per kW-hour)	$0.044	Based on Brown and Caldwell project experience
O&M Labor Rate, average (cost per hour)	$45	Provided by Portsmouth staff (incl. benefits/admin)
Tipping Fees and Revenue		
HSOW tipping fees (cost per gallon)	$0.065	Provided by Portsmouth staff
Imported wastewater cake tipping fee (cost per wet ton)	$60	Assumed

While commodity and labor rates can be extrapolated using historical cost data, soft costs assumptions such as biosolids hauling and disposal costs, tipping fees, and revenue values are developed from recent market studies and regional trends. The soft cost values represent “middle-of-the-road” assumptions and may vary in the future given changes in the market. Sensitivity analyses on the impact of these soft cost parameters can be conducted but were not considered as part of the analysis reported in this TM.

With respect to the impact of flows and loads on lifecycle costs, the model was structured as follows:

- O&M costs were based on WWTF annual average loadings.
- Where alternatives require new equipment, they are sized (and estimated) for design growth projections.
- Rough estimates of project cost are included where new equipment and/or facilities are required. These are purely budgetary numbers that should be vetted as part of a more in-depth condition assessment and review of repair or improvement needs of current facilities.
- NPV is calculated based on the assumptions provided in Table 2-2. These values were obtained from the 2017 Office of Management and Budget (Circular No. A-94).

The general NPV assumptions are shown below in Table 2-2.

Table 2-2. NPV Assumptions	
Component	**NPV Assumption**
NPV term, years	20
Nominal discount rate, annual percentage	2.5%
Inflation rate, annual percentage	2.0%
Real discount rate, annual percentage	0.5%

2.2 Methodology

The process baseline model was used to calibrate the base inputs and model performance. After the baseline was developed, two alternatives were created to model the impacts of creating a RBPF and importing outside sludge and HSOW. These outputs were used with Portsmouth-specific operational costs to generate the lifecycle operational costs. Project capital costs were developed and added to the lifecycle operational costs to determine the NPV of each alternative in 2019 dollars. Development of specific operational parameters is described in more detail below:

- Gas benefit was calculated assuming the CHP facility is sized to accommodate all biogas production. The biogas production rate for each alternative was converted into one million Btu using an assumed 560 Btu/scf. Heat recovery from the future CHP system was assumed to preferentially supply process heat to digestion, with excess potentially used for building heating (not evaluated).
- Labor was adjusted for each alternative to represent the complexity of the process and the amount of equipment needed.
- The maintenance cost for each alternative was based on a ratio of equipment capital cost to account for the increased maintenance activities from new equipment.
- Disposition costs were calculated using the biosolids output from each alternative and the unit disposition costs and distribution assumptions shown in Table 2-1. The analysis assumes that the current solids disposition contract will be the primary disposal option for solids in the future for the City.
- The scheduled maintenance of the CHP system itself was accounted for separately on a dollar per kW hour (kWh) basis given BC's experience with CHP provider service contracts, the details of which are provided in TM 3.

Parameters used to develop the project costs for installation of new equipment are described below:

- The capital costs develop reflect a total project cost and include a 20 percent markup for general conditions and overhead and profit, a 20 percent markup for engineering and implementation, and a 25 percent undefined details design allowance.
- A replacement and residual (R&R) cost was allocated for equipment installed in the alternatives to account for component replacement after 15 years as a ratio of equipment capital cost. Due to the capital projects consisting primarily of tank and building construction, 10 percent of the total initial capital cost was assumed.

2.3 Alternatives Description

The digester feasibility study alternatives were developed from different digester feedstock and solids management strategies described in TM 1. As a result, the following two alternatives were considered for analysis with the planning baseline.

- **Planning Baseline:** Status quo operation
- **Alternative 1:** Thermal hydrolysis with mesophilic digestion with IC engine CHP system for Pease and Peirce Island WWTFs sludge only
- **Alternative 2:** Thermal hydrolysis with mesophilic digestion with IC engine CHP system as described in Alternative 1 and imported wastewater solids and HSOW co-digestion

The alternatives' major construction elements are summarized below in Table 2-3.

Table 2-3. Summary of Alternative Features		
Planning Baseline (Status Quo)	Thermal hydrolysis with Mesophilic Anaerobic Digestion with IC Engine CHP System	
	Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
Major Construction Elements No new equipment installation or process enhancements	**Major Construction Elements** • (2) 0.96 MG anaerobic digesters and control building • Thermo-chemical processing facility • New holding and blending tanks • Gas conditioning and 335 kW CHP facility	**Major Construction Elements** • Imported cake receiving • Thermo-chemical processing facility • (3) 1.4 MG anaerobic digesters and control building • New holding and blending tanks • Gas conditioning and 788 kW CHP facility

Section 3: Economic Evaluation of Alternatives

This section presents capital cost estimates, O&M costs, and the resulting NPV of the project alternatives. Financial evaluation for all alternatives is provided alongside the planning baseline scenario, which represents the status quo operation over the 20-year planning period. The NPV evaluation considers the required capital investment of the alternatives with the projected revenue streams to provide the City with a holistic metric to assess the financial viability of the alternatives and their unique considerations.

3.1 Capital Cost Estimates

Conceptual capital cost estimates developed for the alternatives are presented in Table 3-1. The capital costs are based on Class 5 conceptual cost estimates per the Association for the Advancement of Cost Engineering International (AACEI), which carry a level of accuracy of -50 to +100 percent. Major equipment costs were determined based on vendor budgetary estimates and comparable recent project costs. Where a vendor budgetary quote was obtained, the equipment cost was multiplied by a sequence of standard cost estimate planning factors to develop an overall estimated project cost. The capital costs in Table 3-1 reflect equipment sized for future growth conditions over the 20-year planning period. Capital costs in the table reflect the immediate capital outlay for reference and do not include projected rehabilitate and replacement (R&R) costs assumed to hit at 15 years. Projected R&R costs are included in the total capital number added to the NPV presented later in in Table 3-3. It is assumed that the capital projects are financed through long-term lending programs over the project at standard interest rates.

Table 3-1. Summary of Alternative Features			
Capital Cost Component	Planning Baseline (Status Quo)	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System	
		Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
Dewatered Cake Receiving	$0	$150,000	$540,000
Thermo-chemical Processing	$0	$8,460,000	$16,910,000

Table 3-1. Summary of Alternative Features			
Capital Cost Component	Planning Baseline (Status Quo)	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System	
		Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
HSOW Receiving	$0	$0	$1,730,000
Blend and Storage Tanks	$0	$3,190,000	$4,450,000
Anaerobic Digestion	$0	$18,620,000	$41,890,000
Dewatering Facility	$0	$5,150,000	$5,940,000
CHP System	$0	$3,920,000	$7,090,000
Total Capital	$0	$39,490,000	$78,550,000

a. *Where an equipment vendor quote was obtained the equipment, cost was multiplied by the following factors to develop a project cost: 100% for installation cost, 20% for general conditions and overhead and profit, and 20% for an undefined details design allowance*

3.2 Annual Operating Costs and Revenue

This section presents estimated annual operating and maintenance (O&M) costs and annual revenue projections for the alternatives.

3.2.1 O&M Costs

O&M costs were developed by applying historic unit costs to alternative solids process models. The O&M costs incurred by the planning baseline alongside the project alternatives are presented in Table 3-2 below. Revenue from imported feedstock tipping fees or electricity production are discussed in the subsection below and **excluded** from Table 3-2. The addition of outside wastewater sludge will increase the nitrogen concentration of the dewatered filtrate sent back to the headworks. The additional cost to remove the nitrogen was not included in this model. As stated in TM 2, the increase for Alterative 2 is significant, potentially requiring additional sidestream treatment.

Table 3-2. Summary of Alternative Features			
O&M Cost Component	Planning Baseline (Status Quo)	Thermal hydrolysis with Mesophilic Anaerobic Digestion with IC Engine CHP System	
		Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
Solids Disposition & Hauling Costs	$1,390,000	$580,000	$1,720,000
Electricity Costs	$160,000	$320,000	$610,000
Propane	$45,000	$45,000	$45,000

Table 3-2. Summary of Alternative Features			
O&M Cost Component	Planning Baseline (Status Quo)	Thermal hydrolysis with Mesophilic Anaerobic Digestion with IC Engine CHP System	
		Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
Polymer Costs	$0	$60,000	$220,000
Labor	$280,000	$420,000	$420,000
Contract/Annual Maintenance	$0	$150,000	$340,000
Total O&M	$1,875,000	$1,575,000	$3,355,000

a. These are rough estimates based on experience. The ultimate values will vary depending on regulatory impacts, inflation or local impacts.

3.2.2 Operating Cost Offsets and Revenue Generation

Table 3-3 presents the project revenue projections based on the information available at the time of this feasibility study. The tipping fees represent a $10 reduction to the biosolids hauling and disposal fee paid by the City to account for hauling costs from other facilities.

The electricity offset and revenue rates were developed from a review of reference materials as well as contact with the New Hampshire Public Utilities Commission. Electricity offset was calculated by assuming all electricity production from the CHP system was used to offset historic usage charges (variable charges) at a 90 percent IC engine availability. The demand offset was calculated by assuming that the IC engine would be operating for 10 months out of the year; therefore, credit was applied for the one IC engine for those months.

The New Hampshire Renewable Portfolio Standard (RPS) energy incentives discussed in TM 3 are summarized below. Additional CHP incentives may be available from the electric utility supplying power to the WWTF; however, no programs of this kind were identified at the time of this study. Therefore, no additional incentives were included.

Table 3-3. Revenue Values for Lifecycle Cost Analysis		
Cost Element	Value in Model	Basis
Imported liquid feedstocks tipping fees (price per gallon)	$0.065	BC Project Experience
Imported dewatered cake tipping fees (price per wet ton)	$60	Assumed
Electricity offset rate, average supply and delivery (price per kWh)	$0.10	Historic WWTF rate (Nov 2018)
Electricity demand charge (price per kW)	$13.74	Historic WWTF rate (Nov 2018)
Class I Electricity Renewable Energy Certificates (price per MWh)	$22.50	NH Public Utilities Commission RPS 2018 Review
Class I Thermal Renewable Energy Certificates (price per MWh)	$12.50	NH Public Utilities Commission RPS 2018 Review

Projected revenue streams from the CHP electricity production and imported feedstocks are presented in Table 3-4.

Table 3-4. Estimated Annual Revenue for Feasibility Study Alternatives

O&M Cost Component	Planning Baseline (Status Quo)	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System	
		Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
HSOW Tipping Fees	$0	$0	$35,000
Imported Cake Tipping Fees	$0	$0	$2,326,000
Electricity Offset	$0	$202,000	$526,000
Electricity RECs	$0	$45,000	$117,000
Thermal RECs	$0	$42,000	$152,000

3.3 NPV Analysis

As a conservative measure, no funding or grants are included in the NPV analysis. Electricity production RPS credits are, however, included in the NPV analysis because they are not competitive to obtain. For the baseline NPV analysis, the electrical costs are assumed to increase at the escalation rate identified in Table 2-2.

3.3.1 NPV with Baseline Assumptions

Figure 3-1 shows the baseline NPV results and Table 3-5 summarizes the NPV parameters with a breakdown of capital, O&M costs, and revenue. The NPV figures are presented as bar graphs where the dark bottom portion represents capital investment, the lighter top color represents the annual costs, the green bar represents the revenue, and the gold line represents the NPV.

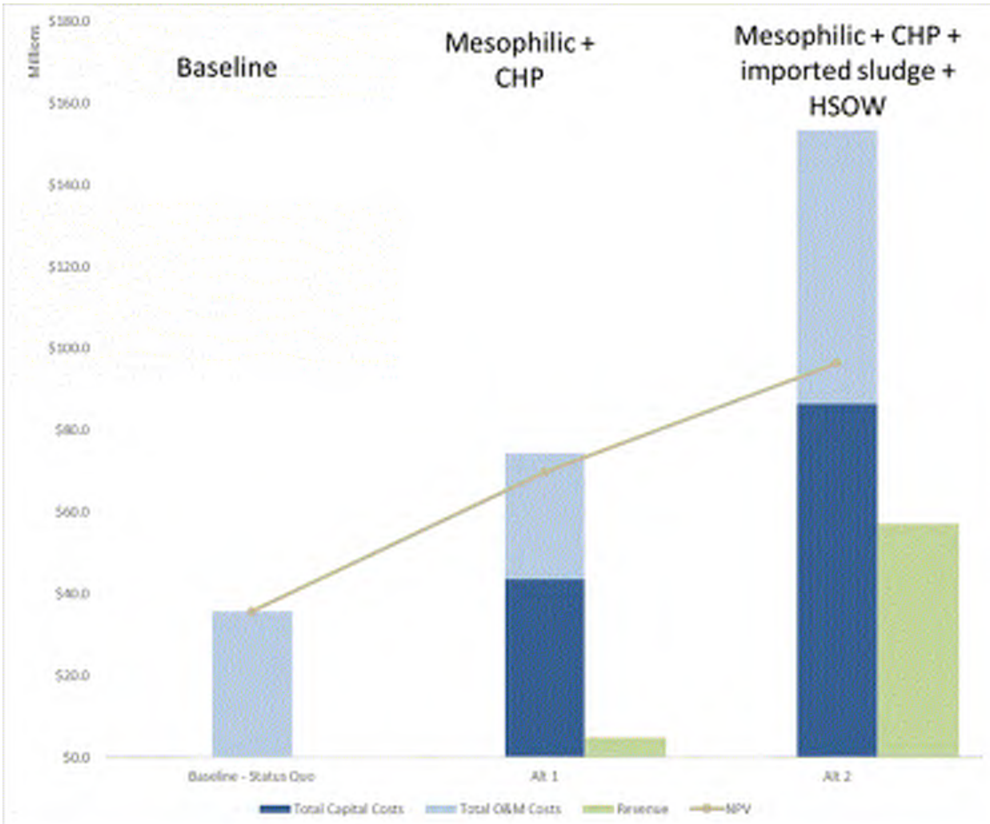

Figure 3-1. Baseline 20-year NPV results

Table 3-5. Estimated NPV for Feasibility Study Alternatives [a]			
Cost Component	Planning Baseline (Status Quo)	Thermal hydrolysis with Mesophilic Anaerobic Digestion with IC Engine CHP System	
		Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids and HSOW
Total Capital Costs	$0	$40,480,000	$84,480,000
Revenue	$0	-$4,700,000	-$57,000,000
Total O&M Costs	$35,700,000	$30,100,000	$63,700,000
20-year NPV Cost	$35,700,000	$65,880,000	$91,180,000

a. *These numbers are based upon the various assumptions and variables indicated in the report, including a Class 5 cost estimate. Changes to key variables or assumptions may impact these results in a favorable or unfavorable manner. A more detailed project vetting should be undertaken as a next step to further refine this analysis.*

Section 4: Summary and Recommendations

Based on current conditions and financial parameters, addition of digesters at Pease WWTF is not financially advantageous. The project lifecycle costs represent an additional $34M and $61M in lifecycle cost compared to the planning baseline with Alternatives 1 and 2, respectively. Addition of digesters does reduce the annual operational and maintenance costs, however the significant capital cost results in a simple payback of 80 years for Alternative 1 and 60 years for Alternative 2.

Technical Memorandum 5

Procurement and Planning

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Technical Memorandum

Prepared for: City of Portsmouth

Project Title: Digester Feasibility Study

Project No.: 152936

Technical Memorandum 5

Subject: Procurement and Planning

Date: May 20, 2019

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List of Abbreviations

CMAR	construction management-at-risk
DB	design-build
DBB	design-bid-build
DBO	design-build-operate
FPDB	Fixed Price Design-Build
GMP	guaranteed maximum price
O&M	operations and maintenance
P3	public-private-partnerships
PDB	progressive design-build
RFP	request for proposal
RFQ	request for qualifications

Section 1: Introduction

The City of Portsmouth (City) operates two wastewater treatment facilities (WWTFs), Pease WWTF and Pierce Island WWTF. The Pease WWTF treats wastewater collected from within the Pease Development Authority. The Peirce Island WWTF treats wastewater collected from the City portions of Rye and Greenland, and all of New Castle. The City has retained Brown and Caldwell (BC) to determine the economic viability of stabilizing and reducing the mass of biosolids generated at the Pease and Peirce Island WWTFs through the creation of a biosolids processing facility using anaerobic digestion.

This Technical Memorandum (TM) 5 provides an overview of various procurement and delivery methods that can be used to implement a biosolids processing facility construction program (Program).

Section 2: Overview of Applicable Delivery Methods

Procurement methods and their resulting delivery models take numerous forms, ranging from standard design-bid-build (DBB) techniques, through construction management-at-risk (CMAR), to turn-key approaches with significant risk transfer, including many variants of design-build (DB), all of which fall under the broad range of collaborative delivery.

The “spectrum” of collaborative delivery methods also can encompass variations that include operations scope and private financing participation. For example, methods that include operations and maintenance (O&M) support are often designated as design-build-operate (DBO). Models that include private equity and financing (often in conjunction with O&M) are often designated as public-private-partnerships (P3). However, issues around O&M responsibility and lifecycle performance are integral to *any* delivery model. Similarly, funding options, including financing, are a critical element of *any* type of delivery assessment. As a result, for the purposes of this inventory, DBO and P3 delivery approaches are **not** considered as separate, stand-alone delivery models, but as options that can be considered in conjunction with *any* of the delivery models under consideration for the Program.

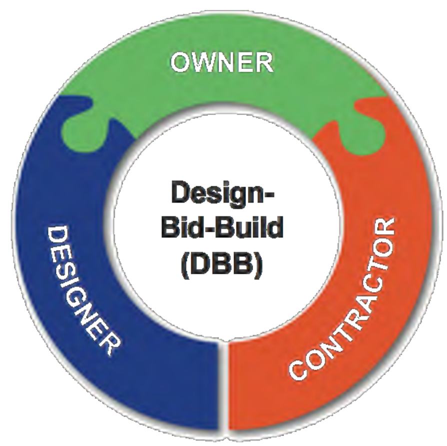
By assessing O&M and funding requirements independently from specific procurement methods, an owner maintains the flexibility to integrate short- and long-term O&M needs on a “mix and match” basis, with the design and construction delivery models determined to be the most appropriate. Funding options and related value for money analyses can also be considered in parallel with the delivery model and O&M analyses.

Another consideration in assessing the collaborative delivery spectrum is permissibility under applicable state and local statutes. As the biosolids processing facility includes projects currently defined only at an early planning phase, it is recommended that the City consider all potential options—assuming no delivery model should be eliminated from consideration based on acceptability from a legal perspective.

Based on the above, the spectrum of available options recommended for consideration by an owner is bracketed as illustrated in Figure 2-1.

Figure 2-1. Potential Project Delivery Spectrum

(Graphics per WDBC Water and Wastewater Design-Build Handbook, 4th Edition)



The project delivery and procurement methods, shown in Figure 2-1, have generally evolved from the traditional DBB approach as the "baseline" most commonly used by public entities. In recent decades, the various collaborative delivery methodologies have emerged as viable alternatives to traditional delivery. These alternatives to DBB seek to better allocate risk and responsibility, save time, and support a selection methodology beyond low-bid capital price. The potential improvement to traditional delivery is supported by re-defined contractual relationships. These relationships are typically organized via two forms:

- *Contractual Relationships* (formal; illustrated with the puzzle piece) indicate firm relationship agreements executed between the given entities; and
- *Embedded Relationships* (illustrated with the dotted green line) represent the collaborative connections required, but not formally contracted, to make the given model a success.

Each of the traditional and collaborative project delivery methods has its own attributes that generally differ in terms of allocation of risks and responsibilities, scheduling and schedule certainty, ownership, performance guarantees, and procurement complexity. In practice, an owner may opt for a combination of delivery methods across various components of the Program.

The primary delivery methods identified in Figure 2-1 are based on the Water Design-Build Council's materials.

2.1 Design-Bid-Build (DBB)

DBB has historically been the most common approach to development of public infrastructure projects. The DBB process has also been used extensively by the private sector to procure new facilities. DBB is considered the "baseline" contract delivery model.

A typical DBB project involves the owner engaging one or more engineering firms to develop a detailed design and specifications and assistance with obtaining local, state, and federal approvals for the project. The owner then uses the detailed design and specifications package as part of a tender package to obtain bids from contractors. The contractor selected through the bidding process is subsequently engaged to construct the Facility in accordance with their bid price and schedule. Typically, the contractor is paid monthly progress payments, and the owner applies holdbacks on payments in accordance with governing state or local law.

Typically, on a DBB project, the design definition and permitting phases must be completed by the Program before the individual projects can release the detailed design for construction. This sequence leads to a longer overall delivery schedule, but also reduces exposing the owner's capital to risks resulting from permitting delays or unexpected changes in permit conditions.

Roles in a DBB project are normally very clearly defined. Design and project performance risks lie with the design team. Construction and scheduling risks lie with the contractor. Operation risks rest with the owner. However, contractors and operators may not have significant input into the design, which can contribute to change orders. Claims during construction are common, and the requirement for some redesign during construction exists, typically at the owner's cost. In addition, design performance or lifecycle responsibility and risk is not typically transferable using a DBB delivery.

Table 2-1. Advantages and Disadvantages of DBB	
Advantages to Owner	Disadvantages to Owner
• Well understood and time-tested process and procedures; • Ability to select subconsultants by qualifications and cost in the traditional manner. Limited at-risk exposure to local professional firms; • Bids to full plans and specifications; • Full going-in construction price known at bid time; • Fully accepted and viable under applicable procurement statutes.	• Linear process takes time; • Little or no designer/contractor collaboration; • Pre-designed approach may not support best potential construction technologies/best practices; • Relies on engineer's estimates until very late in the project; • Hard bids subject to design omissions and resulting change orders; • Limited opportunity to select contractor on qualifications and past performance in addition to price; • Separate contracts for design and construction creates multiple points of contact for owner and does not align business interests; • Not readily conducive to integration of a lifecycle evaluation component or a performance-based operations commitment;

2.2 Construction Management At-Risk (CMAR)

CMAR is also considered a traditional delivery model, albeit an improved approach where an intentional overlap is created between the engineer and the contractor, allowing the contractor to bring construction insight to bear as early as practical in the design process. Sometimes referred to as "design-build-light," this methodology maintains two separate contracts between the owner and the design and CMAR firms, similar to DBB, but encourages collaboration during design to reduce risk once the contractor proceeds to construction in the field.

While in conformance to most traditional procurement processes (where the engineer is selected using traditional professional services criteria), this method introduces the concept of contractor selection without a hard bid of the construction cost. Instead, contractors are generally selected based on their qualifications in combination with their proposed scope of services and fee for service prior to construction as well as their fee and overhead costs for construction services. The ultimate construction cost is developed during the design period, typically in an open-book fashion, and ultimately agreed upon as a guaranteed maximum price (GMP) or lump sum prior to authorizing the start of construction. In some instances, owners convert an initial GMP approach to a lump sum approach during delivery.

Where agreement on a GMP or lump sum cannot be reached, or construction pricing competitiveness cannot be verified, owners often maintain the option to convert the construction scope to a hard-bid process commonly known as the contractual "off-ramp."

While promoting collaboration early in the design process, the formal contract vehicles with separate agreements between the owner and engineer and the owner and contractors are essentially unchanged compared to traditional DBB delivery. During construction delivery, traditional practices for managing contractor change orders, requests for information from the designer, and verification of construction performance, remain unchanged.

Table 2-2. Advantages and Disadvantages of CMAR

Advantages to Owner	Disadvantages to Owner
• Relies on proven, accepted method for selecting professional engineering services based on qualifications; • Integrates constructability earlier in the design process; • Provides contractor-led estimates earlier and allows scope revision during design to meet project budget; • Can reduce overall project risk and contingency; • Can reduce design misunderstandings and resulting potential for change orders; • Allows qualifications and past performance to be considered when selecting a contractor; • Allows permitting process to be integrated into design and construction planning; • Provides an “off-ramp” to convert delivery to DBB approach.	• Relies on engineer’s estimate for initial cost characterization; • Creates a “forced marriage” between designer and contractor that may – or may not – work; • Final construction scope still subject to change order potential; • Added cost to owner for contractor’s pre-construction phase services (although may be offset with construction savings due to early collaboration); • Requires selection of contractor based on fees without knowing full construction price; • Separate contracts for design and construction creates multiple points of contact for owner and does not align business interests; • Does not inherently allow support performance risk transfer - design obligation is traditional “Standard of Care” and construction obligation is to build according to the specified design; • Not readily conducive to integration of a lifecycle approach or a performance-based operations commitment.

2.3 Design-Build (DB)

Under a DB structure, the owner enters into a single contract with a single DB entity (or a consortium of entities acting together as one entity; e.g., joint venture). Generally, the DB contractor has the responsibility of designing and building a project that meets owner-prescribed performance standards. The owner then pays the DB entity based on certain construction and performance milestones being achieved.

In practice, DB can be procured using several different methods, tailored to meet procurement statutes and practice, to align the project complexity and level of design completion anticipated prior to procurement. DB models also support performance risk transfer for design and construction as well as O&M and/or financing.

The various forms of DB differ largely in the type of pricing requested of proposers and in the degree of problem definition developed for the project in advance of procurement and subsequently provided to the design-builder in the request for qualifications (RFQ)/request for proposals (RFP). For DB structure evaluation purposes, two fundamental design-build models will be considered as described further in this section.

2.3.1 Progressive Design-Build (PDB)

In a PDB procurement, a design-builder is selected based primarily on qualifications and, where local practice requires it, limited pricing information generally similar to the CMAR model with an added component of cost for design and preconstruction services (either in a lump-sum or on a not-to-exceed basis for this early work). As the design-builder develops the design, a construction cost estimate is progressively developed, often in conjunction with the 30- and 60-percent levels of design detail. Once the design is well advanced (beyond 60 percent and often up to 90 percent), a GMP is defined for approval by the owner. (As with CMAR, some owners convert GMPs to lump sum pricing.)

If the design-builder and the owner cannot reach agreement on an acceptable GMP or lump sum, the owner can use the completed design as the basis for a hard construction bid procurement. In this case, an “off-ramp” occurs and the project becomes more like a contract DBB, which may impact design ownership.

Progressive procurements are often preferred when a project lacks definition or final permitting, or when an owner prefers to remain involved in the design process while leveraging the schedule, collaboration, and contractual advantages provided by a DB approach. This model is also valuable when regulatory permitting requires well-developed design solutions, or when an owner believes that they can lower cost by participating in design decisions and in managing risk progressively through the project definition phase.

In the case of multiple owners, a Competitive Operating Agreement, active stakeholder involvement, or a single entity owner (project manager or steering committee) should be designated as the point of contact for decision making. It is the owner’s responsibility (or its designee’s responsibility) to provide clear and consistent direction to the design-builder (or designer and contractor).

Owners do not generally use the progressive procurement method when a project’s definition is well advanced prior to the procurement or when a lump sum construction price is preferred (or required) to select a design-builder.

Table 2-3. Advantages and Disadvantages of PDB

Advantages to Owner	Disadvantages to Owner
• Maximum control over project design, construction, and O&M lifecycle costs because final contract is not signed until a large portion of the design is complete; • Single straightforward and inexpensive procurement process can be completed in short timeframe; • Increased marketplace interest due to relatively low proposal preparation cost; • Allows selection of designer and contractor based on past performance, qualifications, and ability to work as a single-entity team with aligned interests for project success; • Provides progressively accurate, contractor estimates of total project costs from earliest point in project through GMP definition; • Provides maximum opportunity for designer, contractor, and owner collaboration to define scope, meet schedule and budget, and tailor subcontracting plan;	• Requires selection based on fee, full construction cost is not known at the time of initial contract; • Existing project design investment may not be of value or use to design-builder; • May not be as fast to deliver as other design-build methods due to potential for extended design/estimate development period, including involvement of numerous stakeholders in the design process; • May not be perceived as being “competitive” for construction pricing; • Requires significant owner staff involvement and resources during design • May limit local/small subconsultant participation due to at-risk nature of the work.

Table 2-3. Advantages and Disadvantages of PDB	
Advantages to Owner	Disadvantages to Owner
• Provides on "off-ramp" to hard-bid construction if GMP is not competitive or cannot be agreed upon; • No contractor-initiated change orders; • Requires little or no design to be completed by owner in advance of procurement and provides maximum flexibility in a final determination of project viability for economic and non-economic factors; • Provides a performance risk transfer mechanism that can be implemented in conjunction with long-term operations commitments; • Single contract and point of contact with owner; • Provides an "off-ramp" to convert delivery to DBB approach.	

In a qualifications-based PDB procurement, the RFQ/RFP typically includes conceptual designs to provide maximum flexibility in the final project determinations—based on the identified risks, performance parameters—with maximum collaboration between the owner, designer, and contractor.

2.3.2 Fixed Price Design-Build (FPDB)

A FPDB RFQ/RFP generally includes a conceptual design as a minimum and a 30 percent design (sometimes referred to as a "bridging" design) as a maximum. Requirements for a performance-based approach are stated as measurable performance objectives of the completed project rather than the specific approaches or processes the design-builder should follow to achieve those objectives. Requirements for a prescriptive approach rely on the pre-design documents as required templates for the design-builder.

FPDB is often considered a highly competitive contract delivery model given its industry-recognized success in supporting large, complex projects.

A performance-based procurement gives a design-builder the flexibility to propose how they will meet the owner's objectives, while requiring proposers to provide a lump sum, fixed price for completion of the project. Alternatively, owners may ask for a "target price" for construction that establishes a not-to-exceed construction price basis, while allowing the owner to collaborate on and adjust the scope during detailed design definition. In this case, the "target" lump sum can be adjusted after award, but only as directed via owner-approved scope changes. Except for these explicitly approved owner changes, the design-builder must conform to their originally proposed price. Thus, this option provides some confirmation of a set price for the project.

Performance-based procurements are often preferred when an owner has a clear vision for how a facility must perform or has limited resources, time, or interest in the specific method for gaining required performance. This model is used to prompt industry's most innovative and cost-effective solutions through what is essentially a design competition, typically in combination with a need to accelerate schedule.

Table 2-4. Advantages and Disadvantages of FPDB	
Advantages to Owner	Disadvantages to Owner
• Maximum potential for design-build cost savings through design innovation during competitive procurement; • Maximum transfer of design-related performance risk to design-builder; • Minimal design work by owner required prior to procurement, resulting in relatively low cost to prepare RFP; • Perceived as "competitive" construction pricing, providing full contract cost at bid time; • Allows selection of designer and contractor based on past performance, qualifications, and ability to work as a single-entity team with aligned interests for project success; • No contractor-initiated change orders; • Provides a performance risk transfer mechanism that can be implemented in conjunction with long-term operations commitments; • Single contract and point of contact with owner.	• If lifecycle cost is not analyzed or operations not included in scope, may result in higher O&M costs or undesirable project features; • Proposal evaluation and selection is relatively complex; • Limited ability to predict what will ultimately be proposed; • Lump sum pricing may include excess risk and contingency cost due to undefined project scope; • Limited opportunity for owner and design-builder collaboration on design during procurement process; • Limited ability for owner to adjust proposed design, scope without resulting in owner-initiated change orders and resulting price adjustments; • May limit local/small subconsultant participation due to at-risk nature of the work; • Limited opportunity for an "off-ramp" to convert delivery to DBB approach.

In a prescriptive FPDB procurement, the RFQ/RFP typically includes at least a 30-percent design completed by an owner's consultant prior to procurement, sometimes referred to as "bridging documents." Requirements are stated in terms of specific approaches or processes the design-builder must follow.

Prescriptive procurements are often preferred when owners are very clear on their preferences and want to use DB to accelerate the schedule while allowing selection of a design-builder based on a combination of qualifications and a lump sum price. While a design-builder may offer a variation or alternative concept to the bridging documents, procurement procedures are often established to require owner review and approval of these exceptions or "alternative technical concepts" in advance of the proposal submittal. With this method, the lump sum price in the design-builder's proposal is only adjusted for specific owner-initiated scope changes, generally due to unforeseen conditions or a change in law or regulatory practice.

2.3.3 Design-Build Operate (DBO)

In a DBO procurement, the DBO entity is selected based on qualifications and fee competition, but not a full, fixed project price. Once selected, a design, construction and operations cost estimate is developed on a progressive, iterative cycle in conjunction with the owner until the project is well enough defined to reach agreement on a design, construction, and operations price. The agreed upon price is characterized as GMP or a lump sum amount, and the project proceeds to final design and construction, with a subsequent operating term on a DBO basis. As a DBO project, the specified performance guarantees are defined in the contract to which the DBO entity is obligated to comply.

The figure above shows how, overall, the delivery and operations would flow in the recommended approach, with either the DBO entity directly providing the O&M or arranging for O&M through a separate O&M contractor. The operations and financing aspect would be embedded in the procurement documents between the owner and DBO entity.

References

Water Design-Build Council, *Water and Wastewater Design-Build Handbook 4th Edition,* WDBC, Edgewater, MD

Technical Memorandum 6

Preliminary Sludge Dryer Evaluation

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Technical Memorandum

Prepared for: City of Portsmouth

Project Title: Digester Feasibility Study

Project No.: 152936

Technical Memorandum 6

Subject: Preliminary Sludge Dryer Evaluation

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List of Abbreviations

°F	degree(s) Fahrenheit
AACE	Advancement of Cost Engineering International
BAF	biological aerated filter
BC	Brown and Caldwell
Btu	British thermal unit(s)
City	City of Portsmouth
DS	dry solids
EPDM	ethylene propylene diene terpolymer
FOG	fat, oil, and grease
ft	foot/feet
ft^3	cubic foot/feet
FTE	full time equivalent
gpm	gallon(s) per minute
H_2O	water
HEX	heat exchanger
HHV	higher heating value
hr	hour(s)
I&C	instrumentation and controls
in.	inch(es)
kcf	1,000 cubic feet
kscf	1,000 standard cubic feet
lb	pound(s)
mm	millimeter(s)
mmBtu	million British thermal units
NA	not applicable
NPW	net present worth
O&M	operations and maintenance
RBPF	Regional Biosolids Processing facility
ROI	return on investment
TM	technical memorandum
TPD	tons per day
TS	Total Solids
US	United States
VOC	volatile organic compounds
wk	week(s)
wtpd	wet ton(s) per day
WWTF	wastewater treatment facility
yr	year(s)

Section 1: Introduction

This technical memorandum (TM) presents the initial findings from a wastewater solids drying economic viability assessment as part of a Regional Biosolids Processing Facility (RBPF) evaluation for the City of Portsmouth (City). This TM contains the costs associated with operating a wastewater solids dryer and a potential return on investment (ROI) to assist the City in developing a wastewater solids management strategy and evaluate opportunities for regionalization. This TM discusses the following steps used to conduct this analysis:

1. Assess wastewater solids projections and potential disposal/disposition rates to establish the basis for the potential savings from wastewater solids drying
2. Evaluate suitable drying technologies
3. Conduct an economic analysis on a life cycle cost basis, comparing near term capital outlay and operating costs to status quo operation with landfill disposal
4. Conclude with final recommendations

Cost proposals were requested from three technology suppliers and are included in Attachment A.

Section 2: Overview

The City's two wastewater treatment facilities (WWTFs), Pease WWTF and Peirce Island WWTF, currently produce approximately 140 tons of wastewater solids every week (a range of120 to 150 tons per week) with solids operation is 5 days a week. The wastewater solids are hauled to a nearby landfill for disposal. The costs associated with managing the solids includes paying for hauling and tipping fees for ultimate disposal at a landfill. The City currently pays $70 per ton of solids for this service. Depending on the existing dewatering equipment performance, the costs associated with hauling and disposing of the solids can range between $8,000 and $11,000 per week. The City is currently completing construction of a new biological aerated filter (BAF) at Peirce Island WWTF that is expected to increase the wastewater solids production substantially. In addition, other WWTFs near the City have recently seen their hauling and disposal costs increase from $70 to $120 per ton due to growing constraints within the local wastewater solids management market. Installing a dryer to reduce the volume of wastewater solids can potentially save the City operating costs and provide protection from future hauling and disposal rate increases. Drying also produces a biosolids product meeting U.S. EPA Class A requirements, increasing the flexibility in end use and disposal options, including land application and commercial fertilizer sale. Dried biosolids also have an appreciable heating value and can be used as a fuel source in combustion processes.

This TM considers installation of a wastewater solids dryer sized to process solids from an anaerobic digestion facility sized to manage the City's solids production only as well as the RBPF (described in the prior TMs). For reference, potential savings for drying of City wastewater solids without digestion are also discussed, although dryer pricing was only provided by one vendor for this scenario. All drying scenarios assume that the dryer is fueled with natural gas from a public utility as the base case digestion evaluation includes biogas utilization in a combined heat and power system. Table 1 provides the estimated solids projections for these scenarios in dry and wet tons per day (TPD) based on averaged solids production over 7 days a week, 365 days a year. The wastewater solids values shown are projected out into the future at year 2025 to capture the impact of the Peirce Island WWTF BAF operation based on the methodology and sources discussed in TM 1 – Flows and Loads Evaluation. The dryers evaluated in this study were sized for

20-year growth projections, and the total operating costs were evaluated at year 2025 so as not to overestimate savings if solids production does not increase as projected. Section 4 of this TM provides the annual savings available in wastewater solids hauling and disposal for these quantities and a comparison to the projected annual operating and maintenance (O&M) costs associated with drying.

Table 1. Wastewater Solids Future Projections for Dryer Installation Scenarios at Year 2025

	Dry TPD	Wet TPD at 25% TS (dewatered cake)	Wet TPD at 92% TS (dried product)
No Digesters	8.7	34.8	9.5
City Only Digesters	4.3	17.4	4.7
RBPF	15.7	62.8	17.4

Values shown represent an averaged operation over 24 hours per day, 7 days a week

Section 3: Alternative Dryers Discussion

This section discusses potential alternative dryer types. A discussion is provided for three conventional dryer technologies as well as an overview of innovative drying technologies in development or new to the U.S. market being deployed in the Northeast.

3.1.1 Principles of Drying in Sludge Application

Drying is a reversible physical/chemical process that removes water from a substance or a mixture. The goal of most sludge drying applications is to reduce the total mass of the disposed solids by evaporating water and in so doing produce a Class A product as defined by 40 CFR Part 503 of the Federal regulations. The regulation states "The requirement for Class A is necessary to prevent the growth of bacterial pathogens after sewage sludge is treated".

There are typically two types of drying methods: indirect and direct. Indirect drying applies an intermediate heat transfer media such as thermal oil or water, generated in a heat exchanger, to dry the sludge. Thus, the heat source or process gas does not come into direct contact with the sludge. Compared to direct dying, the operating temperature is typically lower, but the drying efficiency is lower because of the heat loss in the heat transfer media and operation at a lower temperature. One example of an indirect dryer is a paddle dryer.

Direct drying feeds process gas directly in the dryer without any heat transfer media, such as air or water. This type of drying typically operates at a higher temperature. Examples of direct dryers are a rotary drum dryer and a belt dryer.

Storage facilities for any product should include temperature sensors and provisions for inert gas blanketing for fire prevention purposes. The sections below discuss the different configurations of dryers in municipal sludge application.

3.1.2 Rotary Drum Dryer

Rotary drum dryers have been used to treat wastewater solids since the 1920s. Drum dryers are heated via a fuel-burning furnace that exhausts directly into a long, cylindrical steel drum that rotates on roller bearings. Some drums move the solids through in a single pass, while others use interlocked concentric drums to make multiple passes through the drum. Material is propelled through the drum by the hot gas air stream (750 – 1,200°F) and is continuously lifted by the cylinder flights and cascaded through the hot gas. The dryer exhaust and dried product are passed through an air/solids separator and the dried product is screened and processed for recycling back to the feed solids or routed to storage silos. A relatively large volume of dried recycle product is blended with the dewatered feed solids to increase the average %TS in the blended feed to the dryer beyond the sticky phase of the sludge (60% - 80% TS). When the sludge reaches this dryness region, it becomes crumbly and easier to handle. The sticky region has been correlated with the organic content of different wastewater solids, and shear tests can be conducted to determine at what %TS the sludge moves into the dryness region. Typically, a majority of the air/gas stream (70% - 90%) is recycled to increase the overall thermal efficiencies and help maintain an inert atmosphere, which reduces the risk for thermal events. Recycling the air also minimizes the volume of exhaust air treated in air pollution and odor control equipment. Typically, additional particulate removal is employed followed by regenerative thermal oxidation (RTO) to destroy odors and volatile organic compounds (VOCs).

Given their higher operating temperatures, drum dryers have a higher throughput compared to other drying technologies and typically can achieve a thermal efficiency better than 1,500 Btu/lb of water evaporated. The footprint required for the drum drying system is moderate given the ancillary equipment and operating complexity is high given the high temperatures and potential for dust in the drum. Drum dryers typically produce a more dense, round pellet than other technologies. Rotary drum manufacturers supplying systems in North America include Andritz, Baker-Rullman, Berlie-Falco, Swiss Combi Technology, and Uzelac Industries.

A photograph of a typical rotary drum dryer is shown in Figure 1, a process schematic is shown in Figure 2, and a photo of the end product is shown in Figure 3.

Figure 1. Photograph of rotary drum dryer

Courtesy of Andritz.

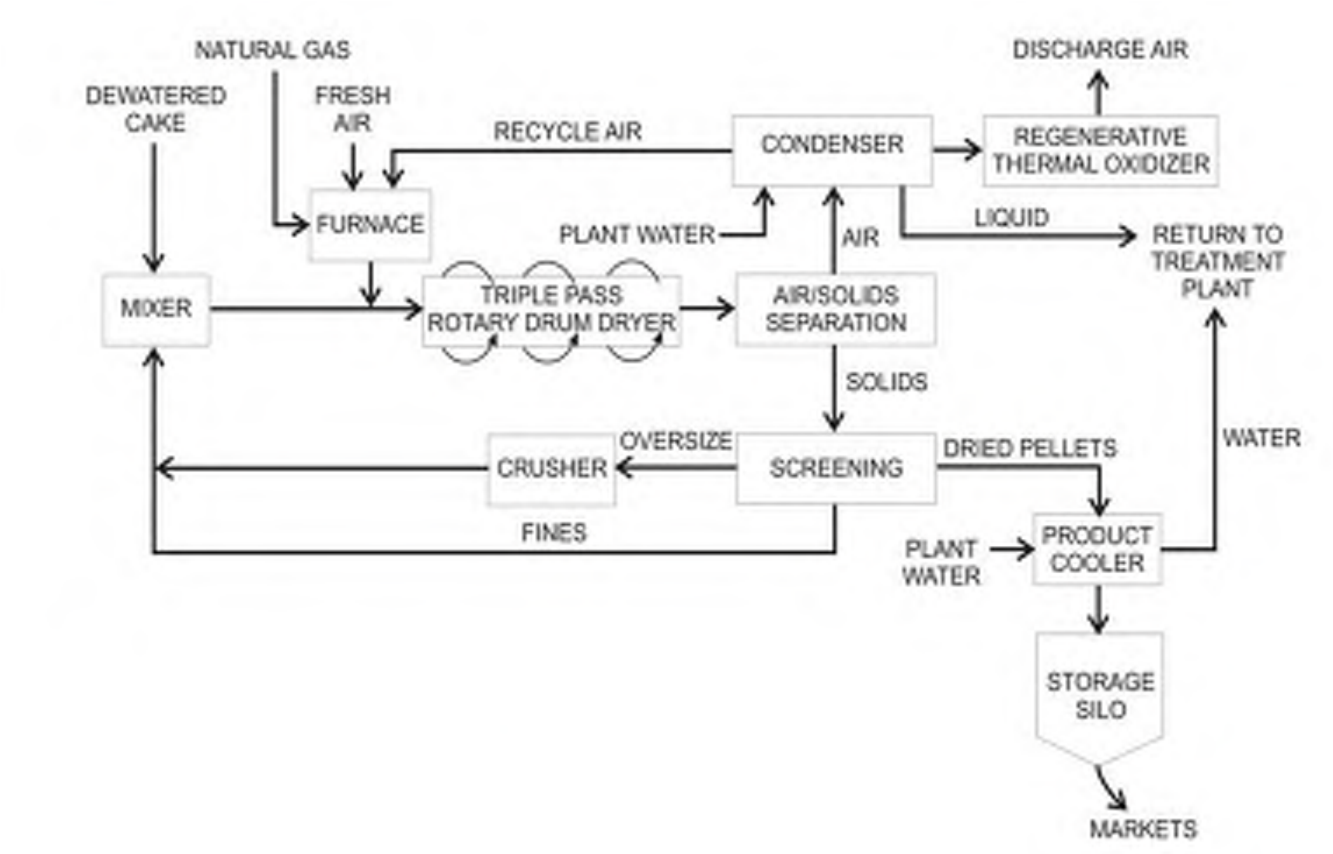


Figure 2. Schematic of triple-pass rotary drum dryer

Figure 3. Photograph of rotary drum dryer product

Courtesy of Andritz.

3.1.3 Belt Dryer

Belt dryer installations are common in both the United States and Europe. They can be either direct or indirect. Heat is typically supplied by a fuel-burning furnace that serves to heat a thermal fluid, water, or flue gas. Because of the lower temperature operation, lower-grade i.e. lower temperature waste heat from other WWTF processes can be used. Dewatered biosolids are distributed via nozzles or perforated plates onto a slow-moving porous belt, providing a large surface area exposed to the hot HEX fluid or process air. Wastewater solids with high amounts of fibrous and stringy materials can plug some types of extruders and may need to be screened for use with these types of extrusion systems. The slow-moving belts provide contact time and generate minimal dust and fines in the dryer cabinet. Depending on the desired product end use, it can be preferred to blend incoming biosolids with previously dried biosolids to reduce the moisture content and to create a more uniform, dense, product.

Overall, belt dryers have historically achieved 1,400–1,700 Btu/lb of water evaporated. The footprint required for belt dryers is relatively large and operating complexity is moderate. Additionally, the end product is dependent upon the belt dryer manufacturer. Spaghetti-like strings or pellet product may be created, and additional processing may be necessary to create smaller, harder particles that are compatible with other fertilizer products. Otherwise the biosolids product may have a higher fines content, causing dust accumulation during storage and use. Examples of belt dryer manufacturers supplying systems in North America include Andritz, Huber, Veolia, and SUEZ among others.

A photograph of a typical belt dryer is shown in Figure 4, a process schematic is shown in Figure 5, and a photo of the end product is shown in Figure 6.

Figure 4. Photograph of belt dryer

Courtesy of Huber.

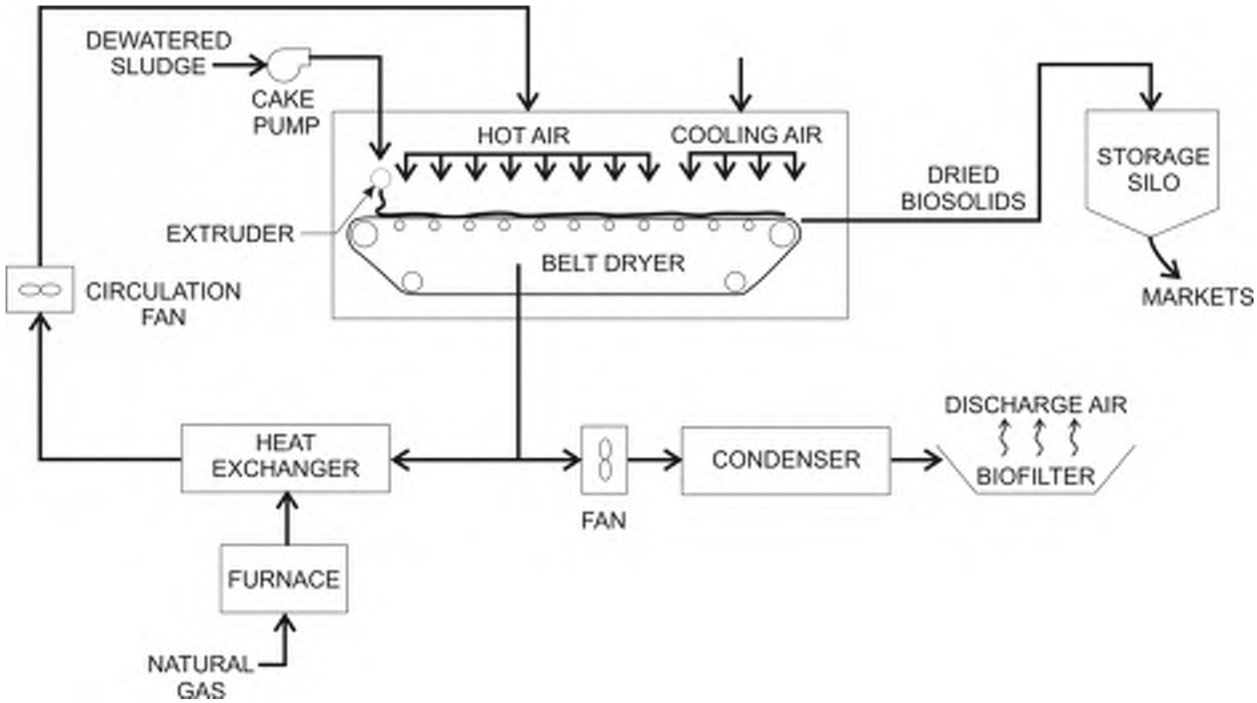


Figure 5. Schematic of one belt dryer option

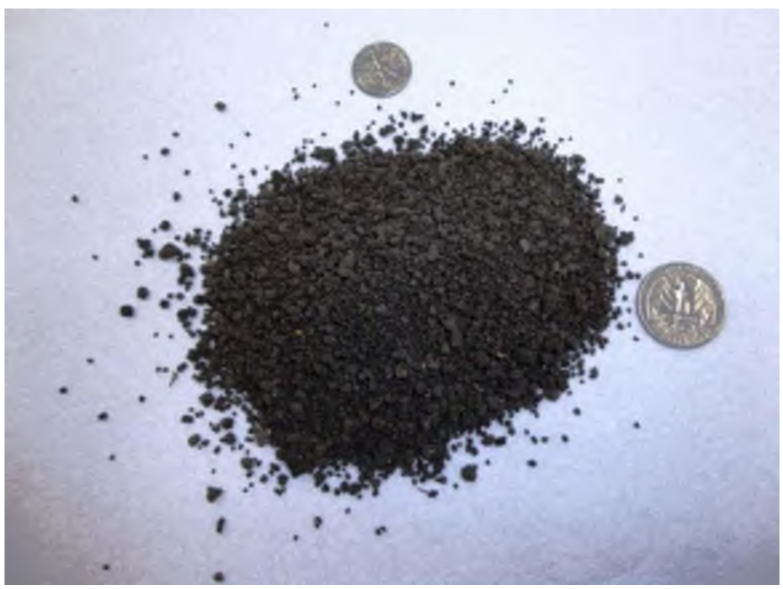


Figure 6. Photograph of belt dryer product

Courtesy of Andritz.

3.1.4 Paddle Dryer

Paddle dryers, also known as auger dryers, are a common dryer type for municipal biosolids. A paddle dryer is a type of indirect drying process that applies a thermal fluid to heat a metal wall that separates the dewatered biosolids from the fluid. Heat transfer occurs by conduction across the metal barrier. A paddle dryer consists of hollow paddles, discs, or augers that are used to turn, agitate, or transport the biosolids throughout a stationary or rotating horizontal, jacketed vessel or trough. A heated fluid, usually steam or specialized thermal oil, circulates within the jacket and the hollow paddles, discs, or augers, allowing for heat transfer with the agitated biosolids. The heat supply is recirculated, reducing heat loss and fluid requirements. Greater degrees of agitation facilitate more heat transfer and less caking on internal dryer surfaces. Overall, paddle dryers achieve 1,400 to 1,600 Btu/lb of water removed.

There have been several instances of paddle dryers requiring major retrofits after several years of operation due to abrasion of the paddles and particularly the trough at the downstream dry end of the dryer. This has been linked to high grit content in a sludge cake as well as repeatedly starting and stopping the dryer.

While a significant advantage of the paddle dryer is a reduced footprint, a disadvantage is the quality of the product, which is often finer and dustier than other dryers. This can be improved by adding an oil to the final product or even pelletizing the final product at additional operational expense. The quality of the final product may not be an issue if it continues to go to landfill but if it is anticipated to be sent for beneficial use then the paddle dryer product may not be acceptable. Implementation of a paddle dryer might require an analysis of viable markets if not disposed of at a landfill, but instead marketed for beneficial reuse. Komline-Sanderson is the most common paddle dryer technology provider in Northern America and other manufacturers include Andritz, Haarslev, and Kenki Corporation.

A photograph of a typical paddle dryer is shown in Figure 7, a process schematic is shown in Figure 8, and a photo of the end product is shown in Figure 9.

Figure 7. 3D model of paddle dryer

Courtesy of Komline-Sanderson.

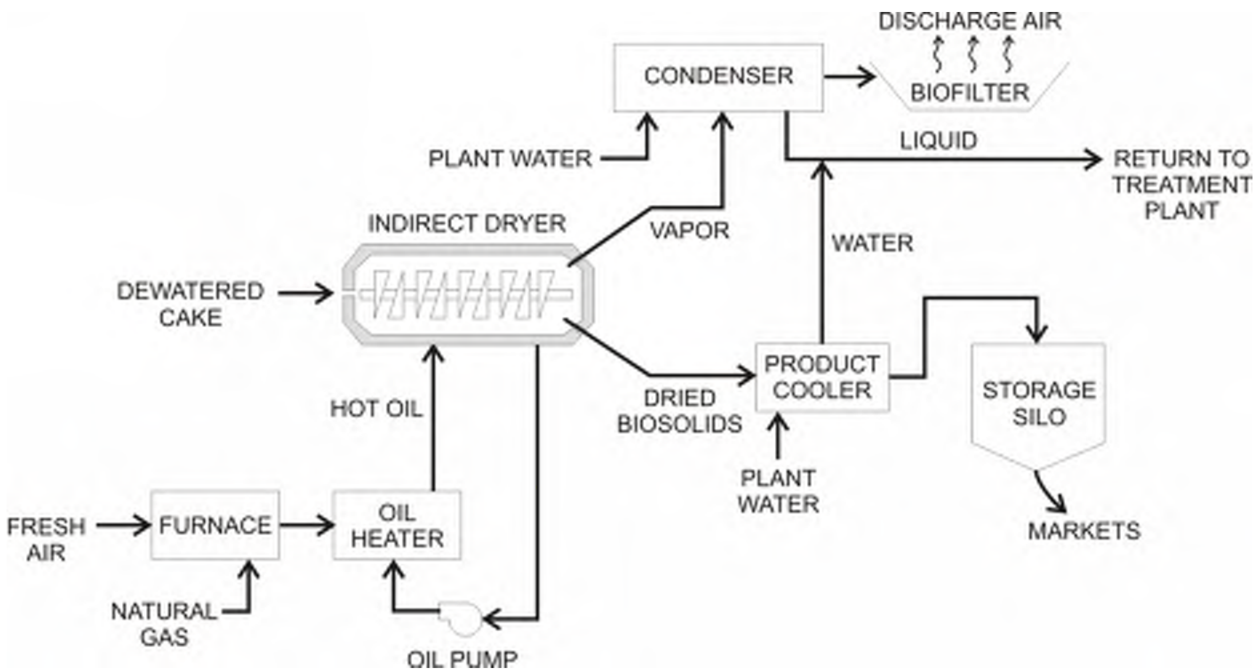


Figure 8. Schematic of paddle dryer

Figure 9. Photograph of paddle dryer product

Courtesy of Andritz.

3.1.5 Embryonic Drying Technologies

Innovative Belt Dryers

Recent advances in drying technology have given rise to new belt dryer configurations with potential advantages over conventional belt drying technology, especially regarding thermal efficiency. Given the recent entry of these technologies into the US municipal market, they haven't yet amassed the evidence to demonstrate long-term, successful operation, but several early adopters have begun to implement these technologies and are gaining experience in their operation.

One example is Gryphon Environmental, who supplies a belt dryer with a vacuum system that has a reported potential to achieve a higher thermal efficiency than a typical belt dryer. The Gryphon dryer controls the pressure and relative humidity of a recirculated process air stream to evaporate water by creating a large moisture differential between the air and sludge, in addition to heating the sludge. Gryphon began operation of their first wastewater solids dryer in Pottstown, Pennsylvania in March 2019 and recently completed manufacturing of two other dryers to be installed at municipal WWTFs in Murfreesboro and Oak Ridge, Tennessee.

Shincci Energy Equipment in China, partnered with US distributor Sunstate Environmental Services, is another innovative belt drying technology supplier that uses an electric dehumidification heat pump process to dry the process air, boosting the thermal efficiency of the system. Shincci dryers have yet to be installed in the US, however Resource Management Inc. has two ongoing projects to install Shincci dryers in Hooksett, New Hampshire and Brattleboro, Vermont and plans to have the units operational and open for site visits in the Fall of 2019.

Thermal Floor Heated Enhanced Solar Greenhouse Dryer

The City of Surprise, Arizona and BC recently collaborated to develop a demonstration project that integrates solar heating with the direct application of radiant heat to biosolids in a solar greenhouse dryer. Solar drying has historically been most viable in southerly sunnier latitudes for municipalities who have land available, and where snow cover is minimal. However radiant heat flooring can be used to increase system throughput and minimize the effects of weather variations to process performance. Typically, radiant heat flooring is incorporated into a concrete greenhouse floor, however the Surprise project uses custom fabricated 304 SS thermal floor plates that provide greater heat transfer, cost savings, and improved durability. The heat input is from hot water generated by concentrating solar panels, meaning there is zero fuel input. Initial pilot operation of the demonstration unit indicates promising thermal efficiency.

The demonstration project has been in operation since 2017 and BC is completing the project to collect and analyze data to determine the costs associated with a full-scale project, potential return on investment, and design parameters for a full-scale regional biosolids drying system. Although the Northeast does not offer the same opportunities for capturing solar heat as the Southwest, the steel floor thermal efficiency and minimal mechanical complexity of this system may make it a viable option for consideration, however additional evaluation would be required.

3.1.6 Additional Dryer Selection Considerations

As noted above, the mechanics of the various drying technologies result in different operating considerations for evaluation. Some of the main operational parameters that drive the evaluation of the dryer technologies include:

- **WWTP Operational Schedule:** All dryers operate more efficiently when run continuously. In particular, paddle dryers can be damaged over time when the components are heated and cooled repeatedly from intermittent operation. Also, intermittent operation substantially increases the size of the dryer compared to 24-hour operation. Operating a dryer at 8-hours per day, 5-days per week increases a dryer size by 2x compared to 24-hour per day, 5-day per week operation. Dryer size not only impacts capital cost, but also building sizes and requirements for the dryer system.
- **Dryer Temperature:** Drum, belt, and paddle dryers all operate at different process temperatures. Low-temperature belt dryers can utilize waste heat from combined heat and power systems but then have a lower throughput and efficiency than other technologies. Higher temperature units can still utilize waste heat such as an industrial stack exhaust stream but can have a higher risk for occurrence of a thermal

event. Similarly, the amount of dust a dryer technology creates also impacts the potential for thermal events.

- **Sludge physical characteristics and chemical composition:** Sludge, especially when undigested, can contain an appreciable amount of grit, hair, fiber, and fats, oils, and grease (FOG). Depending on the dryer materials of construction and mechanical operation the sludge quality can impact dryer operation to different degrees. Dryer technologies that work the sludge against metal surfaces can experience higher amounts of abrasion, while those that recycle the exhaust through heat exchangers can experience tar formation and corrosion. In addition, undigested sludge has higher potential for thermal events due to the higher volatile content
- **End product quality:** Rotary drum dryers produce a more uniform, dense pellet compared to the granular product generated by belt and paddle dryers that can vary in size and fines content. The form and quality of the granular product can limit the end use market unless further processed by pelletizing equipment, and can impact the design of the storage system.

3.1.7 Dryer Suppliers Proposals

BC contacted the dryer suppliers listed below to compare capital cost and operational costs for the different dryer types. Cost proposals were obtained from manufacturers having a demonstrated history of successful operation in the US municipal market. If the level of development for the embryonic technologies discussed are deemed acceptable, the study can be updated to in the future to assess their viability.

Dryer suppliers that submitted proposals as part of this evaluation are:

- Drum dryer: Andritz
- Belt dryer: Huber
- Hot thermal oil paddle dryer: Komline-Sanderson

Table 2 summarizes the three suppliers that provided information and compares the provided operating conditions and process requirements. All dryer systems proposed were sized to operate 24-hours per day, 5-days per week except for the Andritz drum dryer, which was sized for 24-hours per day, 4-days per week operation.

Table 2. Comparison of Alternative Dryers Data

Parameter	Unit	Dryer Type		
		Dryer for City Only Digesters Scenario		Dryer with No Digesters
Type of dryer		Huber BT10 Belt Dryer	Komline-Sanderson paddle dryer: 8W-580	Huber BT16 Belt Dryer
Equipment Cost, June 2019	$	$3.2M	$2.4M	$3.7M
Dryer footprint L ft x W ft x H ft	ft	47' x 20' x 19'	28' x 7' x 15'	67' x 20' x 19'
Operating temperature	°F	203	380	203
Wet solids capacity	Lb/hr	1,600	1,750	4,000
Proposed drying efficiency	Btu/lb	1,300	1,400	1,300
Heating system capacity	mmBtu/hr	1.68	1.80	3.85

Table 2. Comparison of Alternative Dryers Data				
Parameter	Unit	Dryer Type		
Dryer for RBPF				
Type of dryer		Andritz DDS-40 Drum Dryer	Huber BT24 Belt Dryer	Komline-Sanderson Hot oil paddle dryer: 12W-1500
Equipment Cost, June 2019	$	$9.3M	$5.4M	$4.1M
Dryer footprint L ft x W ft x H ft	ft	41' x 18' x 22'	94' x 16' x 19'	38' x 14' x 20'
Operating temperature	°F	1,000	203	380
Wet solids capacity	Lb /hr	9,000	5,900	6,417
Proposed drying efficiency	Btu/lb	1,300	1,300	1,400
Heating system capacity	mmBtu/hr	12.0	6.17	6.50

Attachment A provides details of the suppliers' quotations. All proposals include cake storage and feeding, typical air pollution and odor control equipment and venting, and dried product cooling and loadout equipment.

Section 4: Life-Cycle Cost Discussion

BC conducted a preliminary life cycle analysis to compare the capital and operating costs between the proposed suppliers. This section is based on conceptual level cost development as used for concept screening and should be further developed before use in budget authorization or control.

Table 3 presents the potential cost savings available from reducing the solids hauling and disposal or disposition costs from installing a dryer under the three scenarios discussed in Section 2. Disposition is used here to refer to beneficial end use scenarios that are available with the Class A dried product as opposed to disposal in a landfill. The savings are calculated using each of the scenario's estimated solids production over a range of reasonable hauling and disposal or disposition rates as described in Section 2. The range of hauling, disposal, and disposition rates is provided in the table to demonstrate potential future scenarios that could occur from the continued tightening of the wastewater solids market ($120 per ton), and conversely from beneficial use of digested solids or a dried product. The digested solids disposal/disposition cost of $55 per ton and dried product cost of $40 per wet ton are used as representative costs based on recent Brown and Caldwell (BC) project experience with regional disposition of wastewater solids meeting the EPA Class B and Class A requirements, respectively. However, these parameters should be verified to determine their accuracy, and if further opportunities exist for savings. Many wastewater solids drying systems in the US operate successful distribution programs were customers pick up dried product from the WWTP at no cost to the WWTP, however without a demonstrated market in the area, this scenario was not included in the financial evaluation.

Table 3. Estimated Solids Disposal/Disposition Costs With and Without a Dryer at 2025 Sludge Production							
		Without dryer			With dryer		
Solids Hauling and Tipping Fee ($/wet ton)		$55	$70	$120	$40	$70	$120
End Product (%TS)		25%	25%	25%	92%	92%	92%
No Digesters (8.7 Dry TPD)	Daily*	NA	$2,400	$4,200	$400	$700	$1,100
	Weekly	NA	$17,000	$29,000	$3,000	$5,000	$8,000
	Annually	NA	$880,000	$1,530,000	$150,000	$260,000	$400,000
City Only Digesters (4.3 Dry TPD)	Daily*	$1,000	$1,200	$2,100	$200	$300	$600
	Weekly	$7,000	$8,000	$15,000	$1,000	$2,000	$4,000
	Annually	$370,000	$440,000	$770,000	$70,000	$110,000	$220,000
RBPF (15.7Dry TPD)	Daily*	$3,500	$4,400	$7,500	$700	$1,200	$2,100
	Weekly	$25,000	$31,000	$53,000	$5,000	$8,000	$15,000
	Annually	$1,280,000	$1,610,000	$2,740,000	$260,000	$440,000	$770,000

**Daily values represent an average cost over a 7 day per week hauling regime*

Table 4 presents the preliminary near-term capital and O&M cost analysis. The annual O&M costs represent the burden to the annual savings presented in Table 3 and will be used to develop the net annual economic benefit in Section 5. A more detailed analysis considering preliminary design of the drying system should be performed to further refine these costs if the project is advanced.

Table 4. Wastewater Solids Dryer Initial Life Cycle Cost Assessment								
Cost Element	Description	Dryer for City Only Digesters		No Digesters	Dryer for RBPF			
		Huber Belt Dryer	Komline Paddle Dryer	Huber Belt Dryer	Andritz Drum Dryer	Huber Belt Dryer	Komline Paddle Dryer	
Major Equipment Costs								
Cake Receiving		(Included)	$ 500,000	(Included)	$600,000	(Included)	$ 600,000	
Dryer System and Product Loadout		$ 3,200,000	$ 2,350,000	$3,700,000	$8,000,000	$ 5,400,000	$ 4,100,000	
Dryer Building	$300/sf	$ 1,700,000	$ 900,000	$2,300,000	$5,300,000	$ 3,000,000	$ 1,700,000	
Consulting Design Engineering		$ 500,000	$ 500,000	$600,000	$800,000	$ 800,000	$ 800,000	
Contingency (Un-designed Details)	30%	$ 1,500,000	$ 1,000,000	$1,800,000	$4,000,000	$ 2,600,000	$ 1,800,000	
Installation and Demolition	40%	$ 2,000,000	$ 1,500,000	$2,400,000	$5,600,000	$ 3,400,000	$ 2,600,000	
Total Near Term Construction Costs		**$ 8,900,000**	**$ 6,300,000**	**$10,800,000**	**$23,700,000**	**$ 15,200,000**	**$ 11,000,000**	
Annual O&M Costs								
Drying Efficiency	Btu/lb H2O	1,300	1,400	1,300	1,300	1,300	1,400	
Natural Gas Consumption	MMBtu/wk	280	300	550	830	980	1,050	
Annual Nat Gas Cost	$/yr	$ 200,000	$ 210,000	$390,000	$580,000	$ 680,000	$ 730,000	
Electricity Efficiency	kWh/lb H2O	0.03	0.05	0.03	0.05	0.03	0.05	
Electricity Consumption	kWh/wk	5,400	8,900	10,700	31,800	19,100	31,800	
Annual Electricity Cost	$/yr	$ 30,000	$ 50,000	$60,000	$180,000	$ 110,000	$ 180,000	
Annual System Operation Cost	$/yr	$ 290,000	$ 290,000	$290,000	$290,000	$ 290,000	$ 290,000	
Annual Typical Maintenance Cost	$/yr	$ 70,000	$ 60,000	$80,000	$190,000	$ 110,000	$ 100,000	
Total Annual O&M Cost:	**$/yr**	**$ 590,000**	**$ 610,000**	**$820,000**	**$1,240,000**	**$ 1,190,000**	**$ 1,300,000**	

Assumptions and notes:

a. *Assumes dryer is fueled solely by natural gas*

b. *$13.29 per mmBtu for NG cost (Avg NH Price of NG, U.S. EIA May-18 to Apr-19)*

c. *85% boiler efficiency (Excluded for rotary drum dryer)*

d. *$0.10 per kWhr for electricity supply and delivery, Historic WWTF rate (Nov 2018)*

e. *$13.74 per kW demand charge, Historic WWTF rate (Nov 2018)*

f. *3 FTEs required for dryer facility*

g. *$45 per hour, O&M Labor Rate (Provided by City)*

h. *2% of mechanical equipment cost (typical maintenance cost)*

In accordance with the Association for the Advancement of Cost Engineering International (AACE) criteria, this is a Class 5 estimate. A Class 5 estimate is defined as a Conceptual Level or Project Viability Estimate. Typically, engineering is from 0 to 2 percent complete. Class 5 estimates are used to prepare planning level cost scopes or evaluation of alternative schemes, long range capital outlay planning and can also form the base work for the Class 4 Planning Level or Design Technical Feasibility Estimate. Expected accuracy for Class 5 estimates typically ranges from -50 to +100 percent, depending on the technological complexity of the project, appropriate reference information and the inclusion of an appropriate contingency determination. In unusual circumstances, ranges could exceed those shown. Major assumptions and exclusions for this estimate include the following: enough power is available at the WWTF, no ground improvements are required, and no hazardous materials remediation costs are included.

The following assumptions were used in the development of this estimate.

1. Contractor performs the work during normal daylight hours, nominally 7 a.m. to 5 p.m., Monday through Friday.
2. Contractor has complete access for lay-down areas and mobile equipment.
3. Major equipment costs are based on both vendor supplied price quotes obtained by the project design team and/or estimators, and on historical pricing of like equipment.
4. There is sufficient electrical power to feed the specified equipment. The local power company will supply power and transformers suitable for this facility.
5. Soils are of adequate nature to support the structures. No piles have been included in this estimate.

The following estimating exclusions were assumed in the development of this estimate.

1. Hazardous materials remediation and/or disposal.
2. O&M costs for the project with the exception of the vendor supplied O&M manuals.
3. Utility agency costs for incoming power modifications.
4. Permits beyond those normally needed for the type of project and project conditions.

Section 5: Summary and Recommendations

The goal of this TM was to provide a wastewater solids dryer economic viability assessment to assist the City in developing a wastewater solids management strategy and evaluate opportunities for regionalization. This TM presents conceptual level costs associated with installing and operating a wastewater solids dryer to determine the economic feasibility of drying the wastewater solids produced by a City only digester facility, without any digesters (current conditions) and for the RBPF. An overview of the initial cost evaluation data from Tables 3 and 4 is summarized below in Table 5 along with the resulting range of simple payback projections. The net annual benefit values in Table 5 represent the difference between the annual disposal savings and O&M cost given the different hauling and disposal/disposition scenarios considered in Table 3. The annual O&M costs are taken from the breakdown summary in Table 4.

Table 5. Economic Viability Assessment Overview

	Near Term Construction Costs	Annual Disposal Savings	Annual Dryer O&M Costs	Net Annual Benefit [a]	Simple Payback
Dryer for City Only Digesters	$6.3M - $8.9M	$0.30M - $0.70M	$0.59M - $0.61M	($0.31M) - $0.09M	None – 70 yrs
Dryer with No Digesters	$10.8M (only belt)	$0.62M - $1.38M	$0.82M (only belt)	($0.20M) - $0.56M	None – 19 yrs
Dryer for RBPF	$11.0M - $23.7M	$1.02M - $2.48M	$1.19M - $1.30M	($0.28M) to $1.29M	None - 9 yrs

Notes: a. difference between two previous columns

Table 5 shows the projected operating costs are greater than the potential savings for the most conservative annual disposal savings projections under the City Only Digesters scenario. Even with the more favorable annual disposal savings projections (hauling and tipping fee of $120 per ton for raw dewatered cake and $40 for dried product), the project simple payback is over 70 years. This is reasonable given the smaller volume of wastewater solids in this scenario that reduce the value of potential savings when compared to the fixed operating costs of running a dryer (namely operations labor). If the dryer can be operated with existing WWTF staff, or solids hauling and disposition rates increase beyond the range considered in this study then the dryer would result in a more favorable economic evaluation. For example, if the plant only had to add one FTE the corresponding payback is 23 years. Additionally, at a raw dewatered cake hauling and tipping fee of $160 per ton the corresponding payback drops further to 13 years if the dried product hauling and tipping fee is $40 per ton and the plant only adds one additional FTE.

The dryer for the scenario without digesters (current conditions) represents the economic viability of only the belt dryer, as this was the only technology supplier to provide a quote for this scenario. The net annual benefit ranges from a loss of $0.20M to a savings of $0.56M per year. This range is due to the greater variability in potential savings compared to City Only Digesters scenarios, given the larger volume of initial wastewater solids considered. The most optimistic projected payback period is 19 years given the hauling and tipping fees assumed in Table 3. If the raw dewatered cake hauling and tipping fee increased to $160 per ton then the simple payback drops to 10 years. Additionally, the payback would be reduced to 14 years if the dryer only required addition of one new FTE. Further investigation into the physical characteristics and chemical composition of the City's wastewater solids would be recommended to ensure a good match with the drying technologies considered under this scenario. Undigested solids can present additional quality considerations such as FOG, hair and fiber, and grit in the solids that may impact the dyer operation to a greater extent than digested solids, as well as increased risk of thermal events.

The dryer for the RBPF results in a net annual impact ranging from a loss of $0.28M to a savings of $1.29M per year. When the most optimistic net annual benefit calculated is applied to the lowest near-term construction cost alternative (Komline-Sanderson paddle dryer), the project has a simple payback of 9 years. If the raw dewatered cake hauling and tipping fee reaches $160 per ton the corresponding payback drops to 6 years.

Additionally, this study did not consider the impact of fueling the dryers with digester gas, but that would substantially improve the economics of all scenarios. For example, if the RBBF dryer were fueled by digester gas alone, the payback would reduce from 9 to 6 years. Future evaluation could also consider drying the wastewater solids to 80%TS for volume reduction (would not meet Class A requirements) to eliminate the risk of combustible dust formation and reduce the dryer size.

Although the range of solids hauling and disposal and disposition costs are theoretical at the time of this report, recent experience in the New England wastewater solids market supports the likelihood of these rates coming to bear in the near future. Wastewater solids management costs have been rising for years given the steady closure of landfills and wastewater solids incinerators, as well as public objection to odors and contaminants of emerging concern. Wastewater solids in this market also provides a greater level of cost control, by shifting the O&M costs from the wastewater solids management market to more readily known commodities such as natural gas and labor. As noted above, some agencies are able to distribute dried product at zero cost, which if possible at Portsmouth, would substantially improve the payback period.

In summary, wastewater solids drying with natural gas demonstrates marginal to no benefit when considered for the City only digesters scenario, and under the current hauling and disposal rates without digesters and for the RBPF. However, when assuming the increased hauling and disposal rate of $120 per ton observed at neighboring WWTFs and a lower dried product hauling and disposition rate of $40 per wet ton, the dryer for the current conditions (no digesters) and RBPF demonstrates a 19 and 9 year payback, respectively, with the lowest near term construction cost alternative.

In addition to operational cost savings, wastewater solids drying also provides a benefit in risk management, specifically long-term cost control, and the associated environmental benefit of producing a dried product with greater potential for beneficial reuse. As part of the due diligence necessary in the progression from initial economic viability assessment (this study) to design, the City would best be served by further developing these alternatives and refining the core assumptions to ensure more accurate cost estimates for budget authorization, as well as to identify opportunities for further system optimization, capital cost reduction and final product disposal or disposition. This process should also formulate specific design criteria to include in preliminary design to ensure the dryer technologies considered meet the goals and requirements of the City and all relevant permitting authorities. Additionally, a more detailed screening evaluation should be performed to select a preferred dryer technology based on non-cost criteria such as odors, safety, permitting requirements, operating schedule, and equipment footprint.

References

Peeters, B., Dewil, R., Smets, I., Challenges of Drying Sticky Wastewater Sludge, *Chem. Eng.*, September, pp. 51-54, 2014.

Title 40, Code of Federal Regulations, Part 503 – Standards for the Use of Disposal of Sewage Sludge, US EPA, Washington, D.C.

WEF Fact Sheet, Drying of Wastewater Solids, WEF Residuals and Biosolids Committee Bioenergy Technology Subcommittee, 2014

WEF Manual of Practice No. 8, *Design of Municipal Wastewater Treatment Plants*, Chapter 26, WEF, ASCE, and EWI, 2010

Attachment A: Dryer Vendors' Quotations

Huber Belt Dryer Proposal

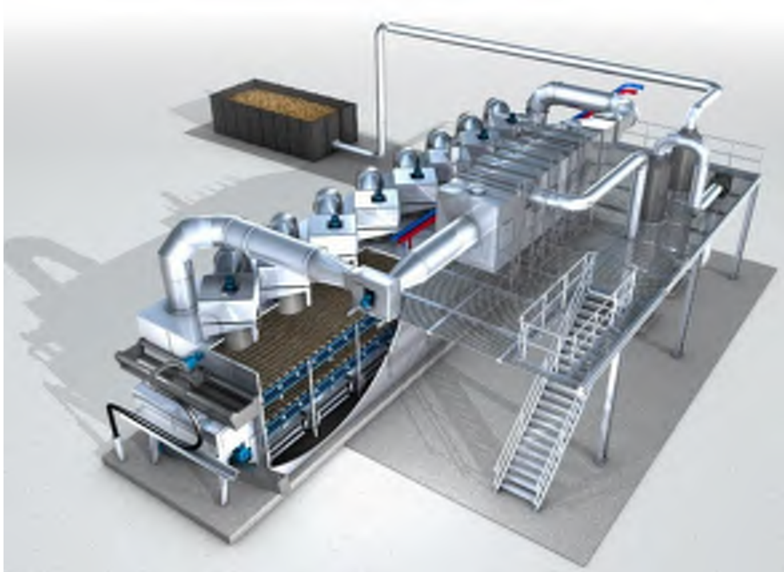
City Only Digesters Scenario (1,600 dry tons per year)

Budgetary Proposal

Project Name:
Portsmouth, NH

Equipment Type:
BT 10 203°F
95°C

Proposal Date:
6/24/2019



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Phone: (704) 949-1010
Fax: (704) 949-1020

Belt Dryer Design Summary

Portsmouth, NH June 24, 2019

Sludge Characteristics:

Upstream Process:	Information not provided
Digestion Process:	Information not provided
Sludge Type:	Unknown
Sludge VSS:	Information not provided
Sludge Protein Content:	Information not provided

Project Design Parameters:

Sludge Feed Rate:	1,680 dry ton/yr	(1,527 dry tonne/yr)
Sludge Feed Rate:	7,000 wet ton/yr	(6,364 wet tonne/yr)
Inlet Cake Concentration:	24%	
Calculated Sludge Loading Rate:	1,680 dry ton/yr	(1,527 dry tonne/yr)
Calculated Hydraulic Loading Rate (per unit):	7,000 wet ton/yr	(6,364 wet tonne/yr)

Equipment Recommendation:

Recommended unit model:	Huber Dryer BT 10	
Recommended unit quantity:	1	
Project Design Calculations:		
Estimated Dry Cake Solids Out:	92%	
Solids Loading Rate Out:	1,826 wet ton/year	(1,660 wet tonns/year)
Annual Water Evaporation Requirement:	5,174 ton water/year	(4,704 ton water/year)
Assumed Annual Operation Time:	8,000 hr/year	
Hourly Water Evaporation Requirement:	0.65 ton water/hr	(0.59 ton water/hr)
	1,293 lb water/hr	(587 kg water/hr)

Equipment Design Parameters:

Thermal Heat Source:	Information Not Provided
Estimated Heat Supply Temperature:	203°F (95°C)

Equipment Requirements:

Heat Demand:	1,300 Btu/lb water evaporated
	1.68 MBtu/hr
	0.84 kWh/kg water evaporated
	493 kW
Electrical Demand:	.03 kWh/lb water evaporated
	.07 kWh/kg water evaporated
	40 kW

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Phone (704) 949-1010 · Fax (704) 949-1020 · huber@hhusa.net · www.huber-technology.com
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Notes and Assumptions

Portsmouth, NH June 24, 2019

1. Equipment specification and drawings are available upon request.
2. If there are site-specific hydraulic constraints that must be applied, please consult the manufacturer's representative to ensure compatibility with the proposed system.
3. Huber Technology warrants all components of the system against faulty workmanship and materials for a period of 12 months from date of start-up or 18 months after shipment, whichever occurs first.
4. Budget estimate is based on Huber Technology's standard Terms & Conditions and is quoted in US dollars unless otherwise stated.
5. Equipment recommendations are based on information provided to Huber Technology. Subsequent information which differs from what has been provided may alter the equipment recommendation.
6. Pricing is based on Huber's standard control panel arrangement.

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Equipment Summary

Portsmouth, NH June 24, 2019

<u>Dryer System:</u>

One (1) Huber BT 10 Dryer, including:

- One (1) Belt
- Support Frame
- Belt Drive
- Belt Guides
- Drive Motor
- Tension Adjustors

Air Duct System:

- 304 Stainless Steel Materials
- Four (4) Recirculation Air Ducts
- Fresh Air Inlet and Exhaust Air Outlet

Four (4) Recirculating Fans:

- 304 Stainless Steel Materials
- Drive Motors

Air Ventilator

- 304 Stainless Steel Casing Material
- Drive Motor

Exhaust Fan:

- 304 Stainless Steel Casing Material
- Drive Motor

Heat Exchanger and Recovery System:

- Ten (10) Main Heat Exchangers
- Heat Recovery System including Heat Exchangers - 304 Stainless Steel

Outlet Conveyor:

- 304 Stainless Steel Materials
- Shafted Screw
- Drive Motor
- Carries Sludge to end of the dryer

<u>Ancillary Equipment</u>

- Control Panel with Allen Bradley PLC and HMI
- Allen Bradley MCC
- Live Bottom System with Feed Pump (approximately 60 yd^3)
    - Note: Size and Price Dependent on Final Design
    - Each Live Bottom will have two (2) feed pumps included
- Heat Recovery and Cleaning Pump
- Scrubber System

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- Dry Product Transport Conveyor
- Hot Water Boiler

Freight and Startup:

- Standard Huber Recommended Start-up Services
- Freight to jobsite.

Total Price: $ 3,200,000 (per unit)

Dryer Options

Portsmouth, NH June 24, 2019

Optional Items which can be supplied by Huber (but are not included in the above pricing):

Dry Product Storage Silo:

Dry Product Processing:

Items Not Supplied by Huber

Portsmouth, NH June 24, 2019

Items not included in the above offering:

- Wiring and Piping between all supplied equipment
- Installation
- Building structures
- Site Preparation
- Required maintenance platforms and cranes

Estimated Operational Cost

Thermal Energy Consumption

Dyer Energy Usage	1,300 Btu/lb water evaporated	(0.840 kWh/kg water evaported)
Water Evaporation	1,293 lb water/hr	(587 kg water/hr)
Hourly Usage	1.68 MBtu/hr	(493 kW)
Assumed Operation	8,000 hr/year	

Natural Gas Cost

$12.00	/1000cuft *
1.037	MMBTU/1000cuf *
85%	Boiler Efficiency
$22.89	/hr
$183,141	/yr

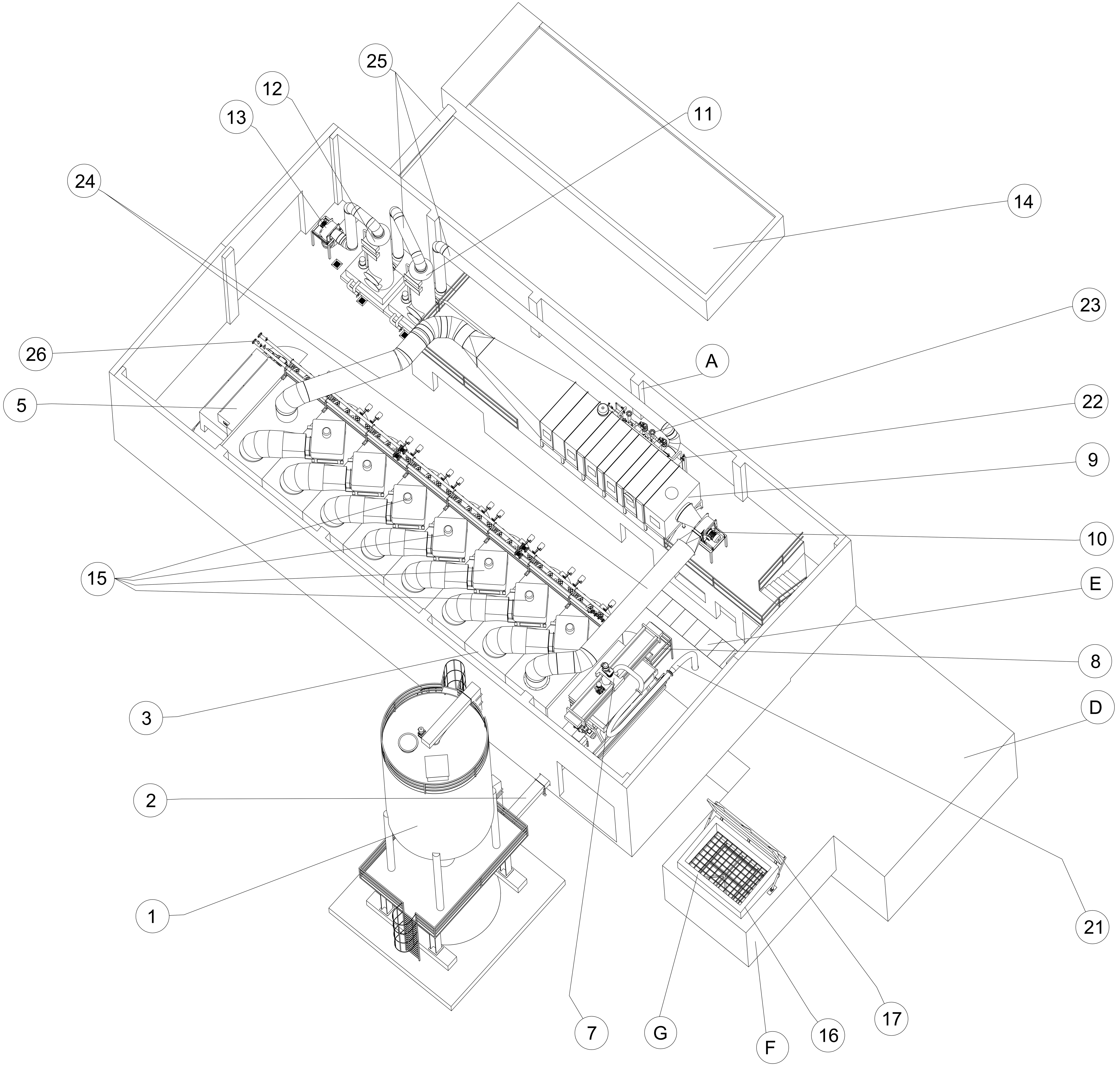
Electrical Energy Consumption

Dyer Energy Usage	0.03 kWh/lb water evaported	(0.07 kWh/kg water evaported)
Water Evaporation	1,293 lb water/hr	(587 kg water/hr)
Hourly Usage	40.1 kW	
Assumed Operation	8,000 hr/year	

Electrical Energy Cost

$0.16	/kWh **
$6.42	/hr
$51,326	/yr

*Thermal Energy Cost - Reference - Commercial Cost
https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PCS_DMcf_m.htm
https://www.eia.gov/tools/faqs/faq.php?id=45&t=8
**Electrical Energy Cost - Reference - Commercial Cost
https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a



Pos. Item	Beschreibung	Description
A	Trocknerhalle	Dryerbuilding
B	Elektroschaltraum	Electrical Room
C	Auffangwane bodenbündig für Chemikalien	Collecting pan for chemicals
D	Wartungskeller	Maintenance cellar
E	Bergeöffnung	Maintenance opening
F	Nassschlammbunker	Wet sludge Storage
G	Einwurföffnung für Nassschlamm	Wet sludge acceptance
H	Chemikalienraum	Room for chemicals

Pos. item	Bezeichnung	description
1	Silo	silo
2	Becherwerk	bucket chain conveyor
3	Trockner	dryer
4	Kopfstück 1	head end 1
5	Kopfstück 2	head end 2
6	Transportschnecke Ro8T	screw conveyor Ro8T
7	Pelletierer	pellet former
8	Wartungsbuehne	maintenance platform
9	Kondensationsstufe	condensation unit
10	Ventilator für Kondensationsstufe	fan for condensation unit
11	Luftwäscher sauer	scrubber acid
12	Luftwäscher basisch	scrubber alcaline/oxidizing
13	Fortluftventilator	exhaust fan
14	Biofilter	biofilter
15	Prozessluftventilator	process air fan
16	Einfallschutz	fall protection
17	Bunkerdeckel	hydraulik bunker cover
18	Schubboden	live bottom wet sludge
19	Hydraulikaggregat	hydraulic power unit
20	Dickschlammpumpe	wet sludge pump
21	Dickschlammleitung	wet sludge pipe
22	Waermerueckgewinnung	heat recovery system
23	Kühlwasserverrohrung	piping for cooling water
24	Lüftungsrohr Umluft	air pipe condensation air
25	Lüftungsrohr Fortluft	air pipe exhaust air
26	Heizungsverteiler	heating distribution

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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Technische Aenderungen vorbehalten / Subject to change

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				Norm.		

Massstab/Scale: 1:50

Trockner BT+ 16

dryer BT+ 16

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
000001_290270		1/7

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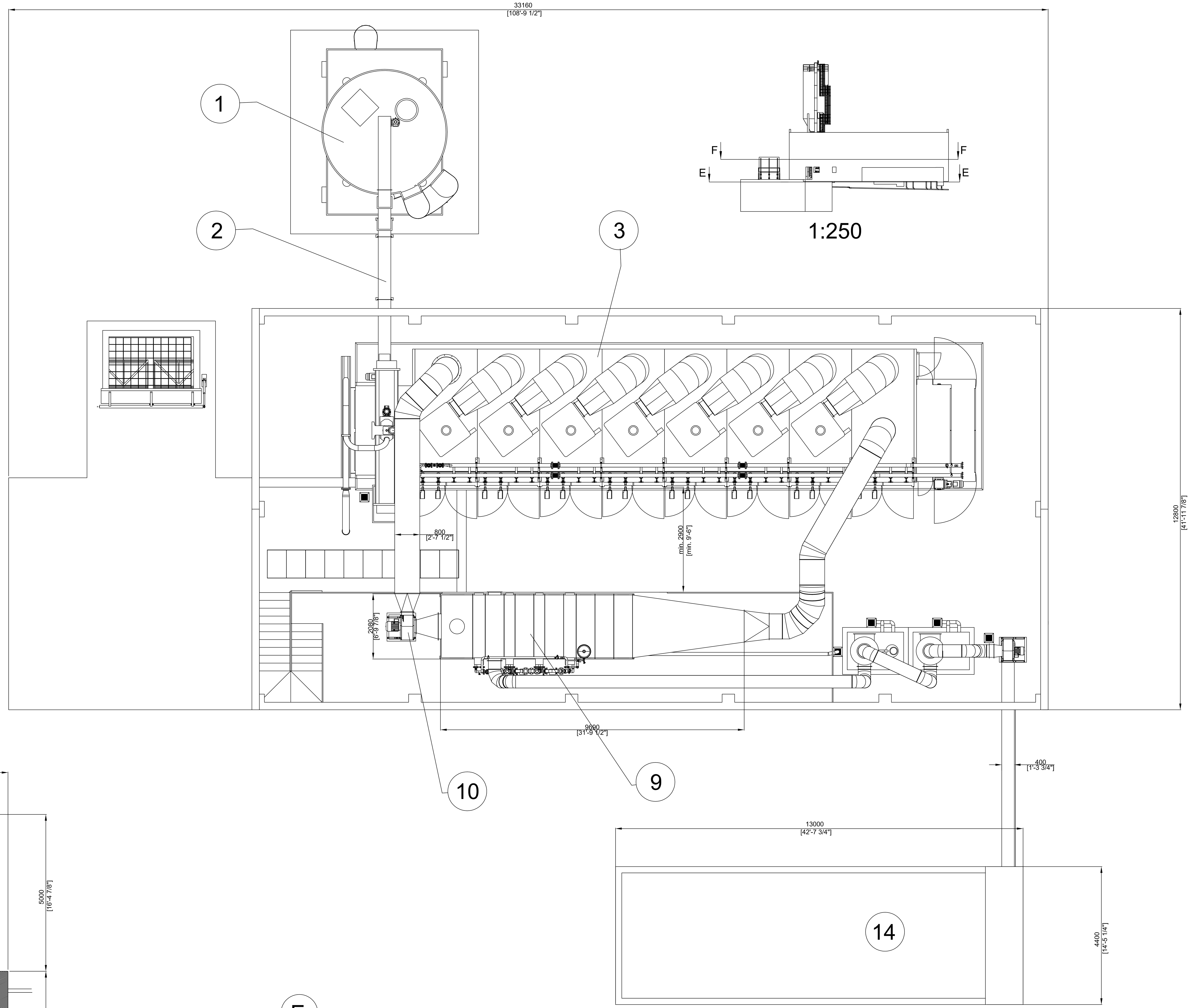
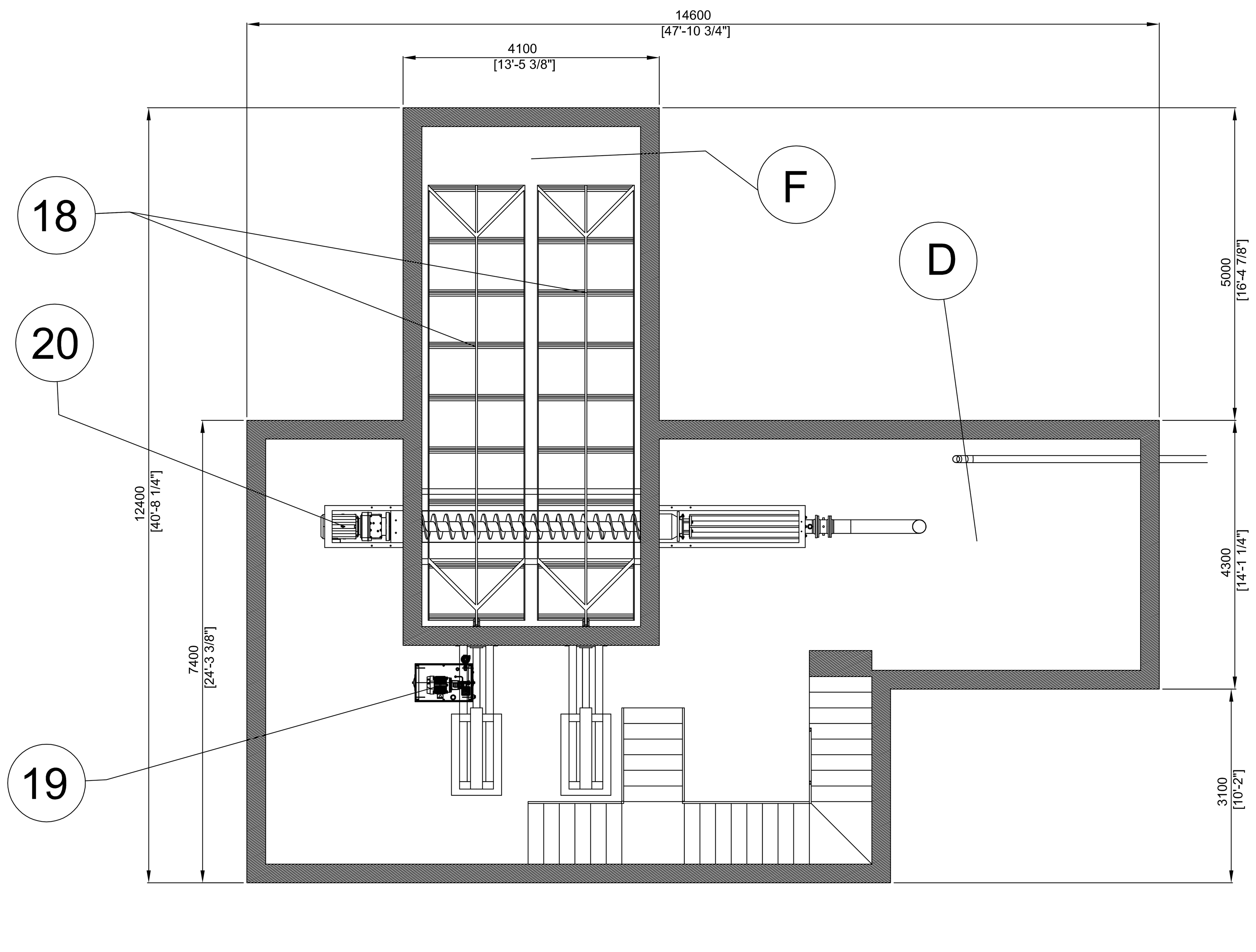
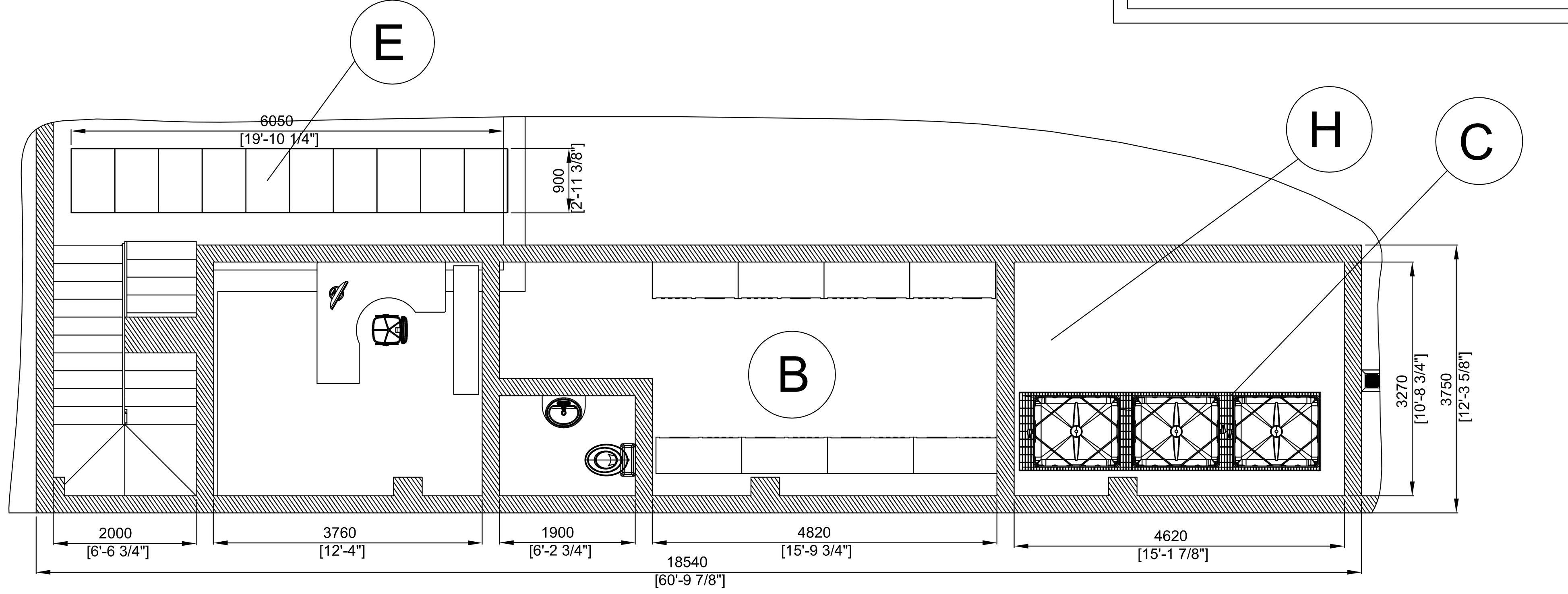




E-E



F-F

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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				Norm.		

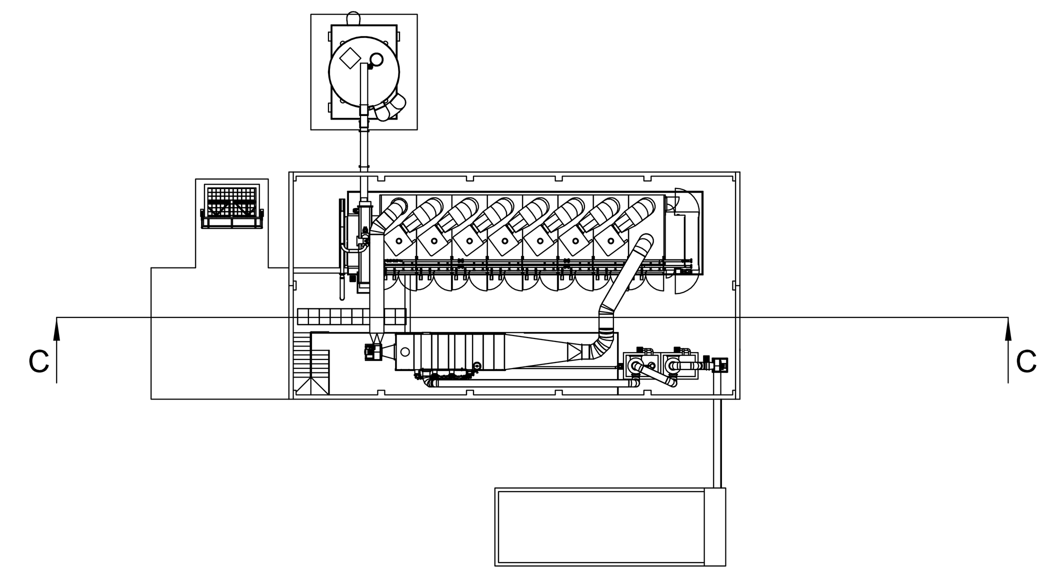
Massstab/Scale: 1:50

Trockner BT+ 16

dryer BT+ 16

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project | Art.-Code Item Code: 000001_290270 | Blatt Sheet: 2/7



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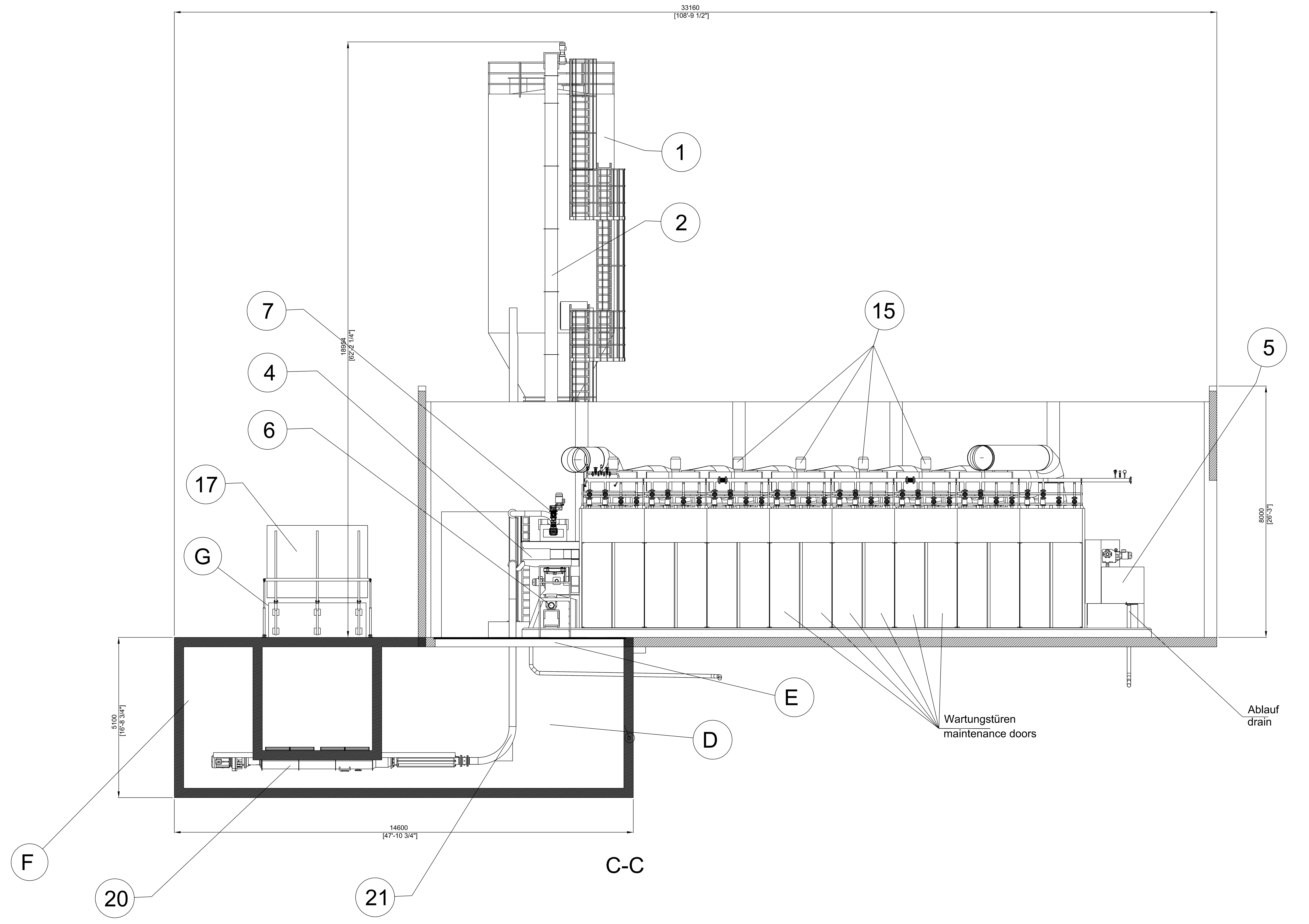

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Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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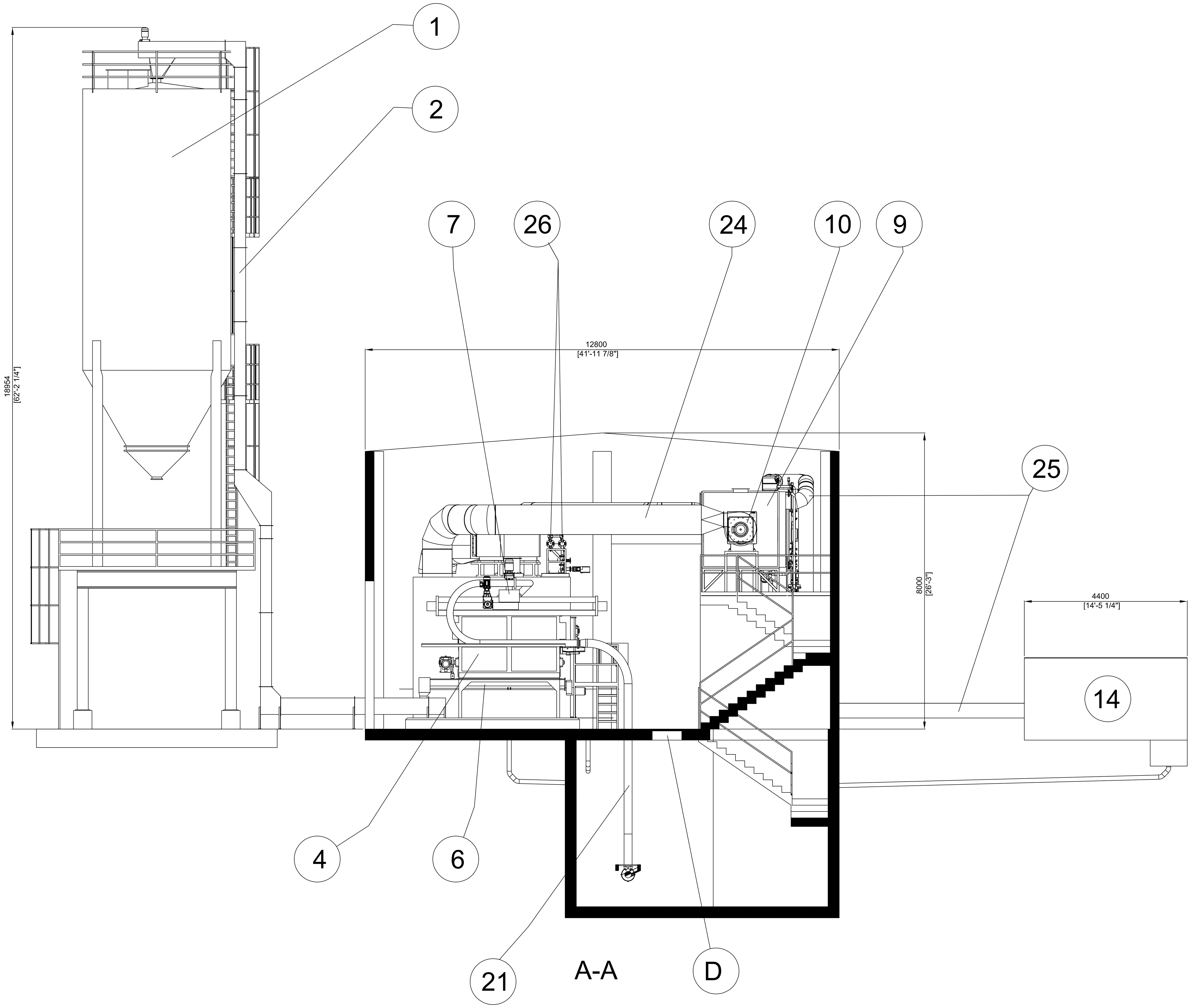
Gepr./Appr.	10.12.2013	hal
Norm.		

Massstab/Scale: 1:50

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt / Project – Art.-Code / Item Code: 000001_290270
Blatt / Sheet: 3/7



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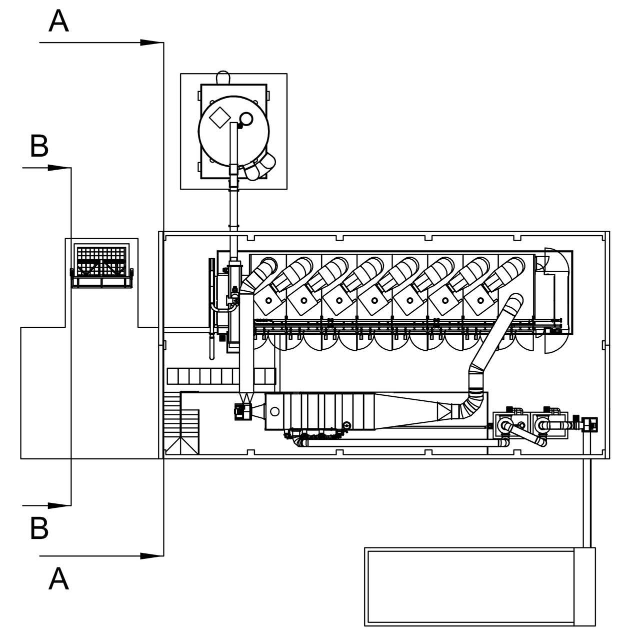

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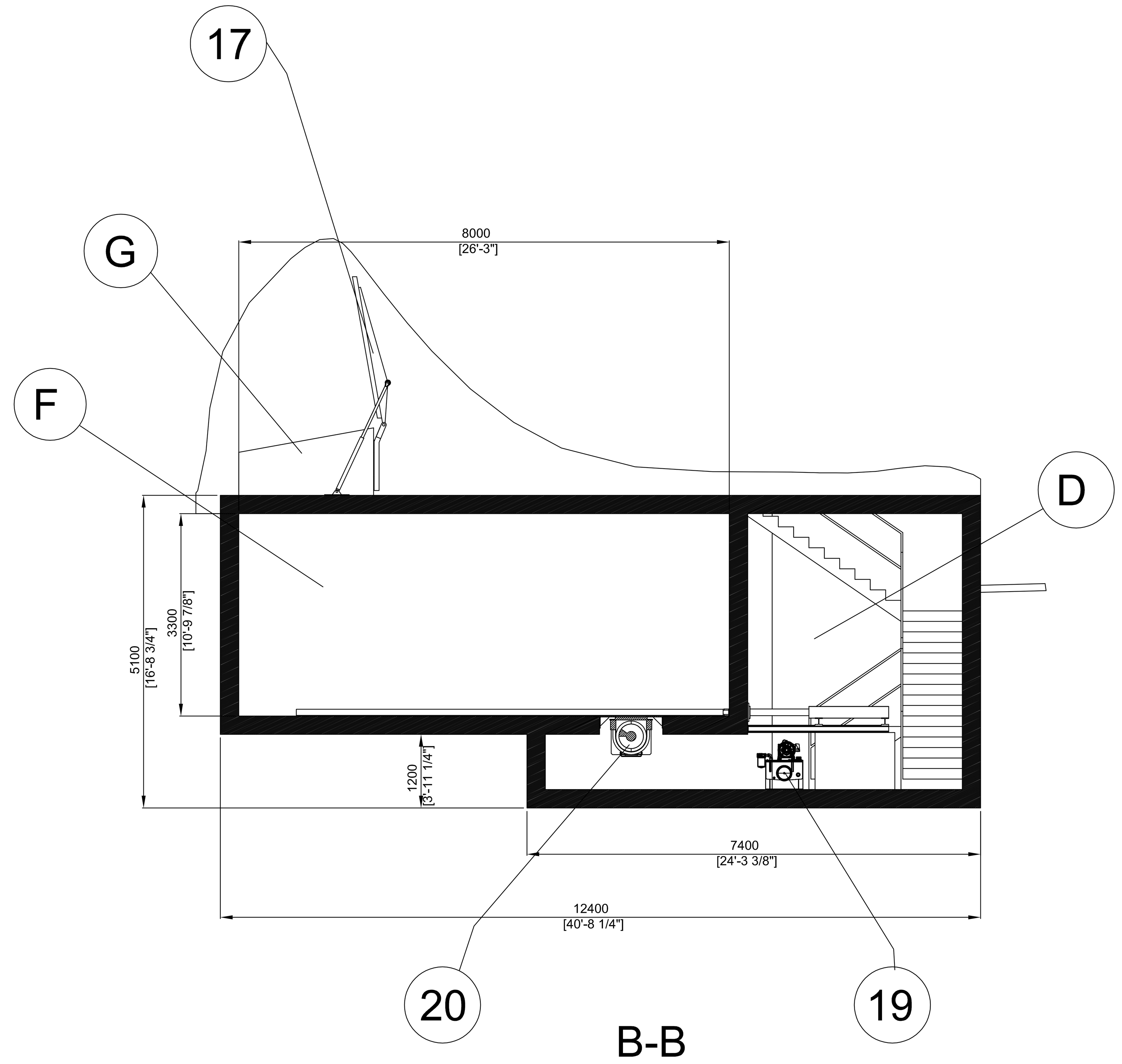

B-B

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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Massstab/Scale: 1:50

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
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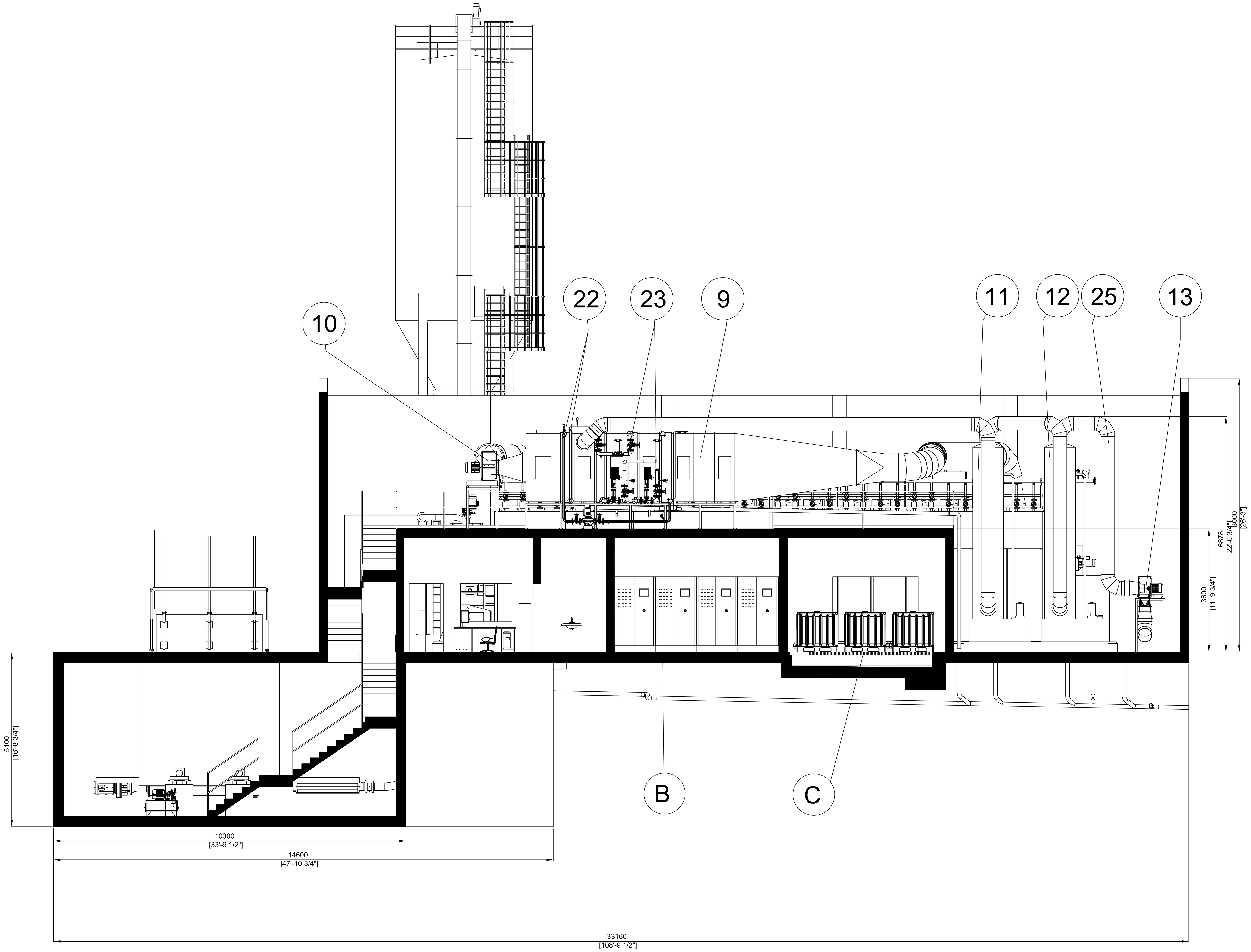

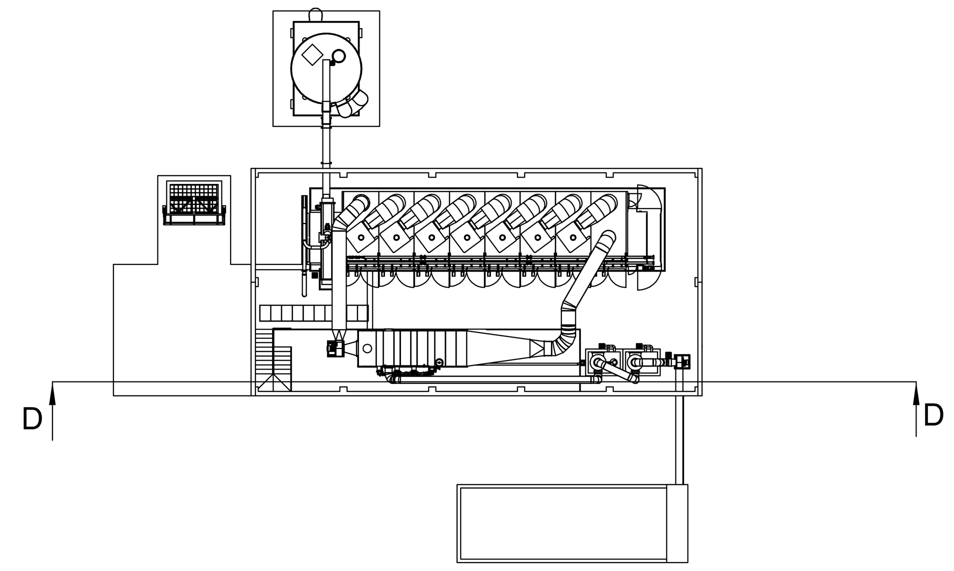

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				Norm.		

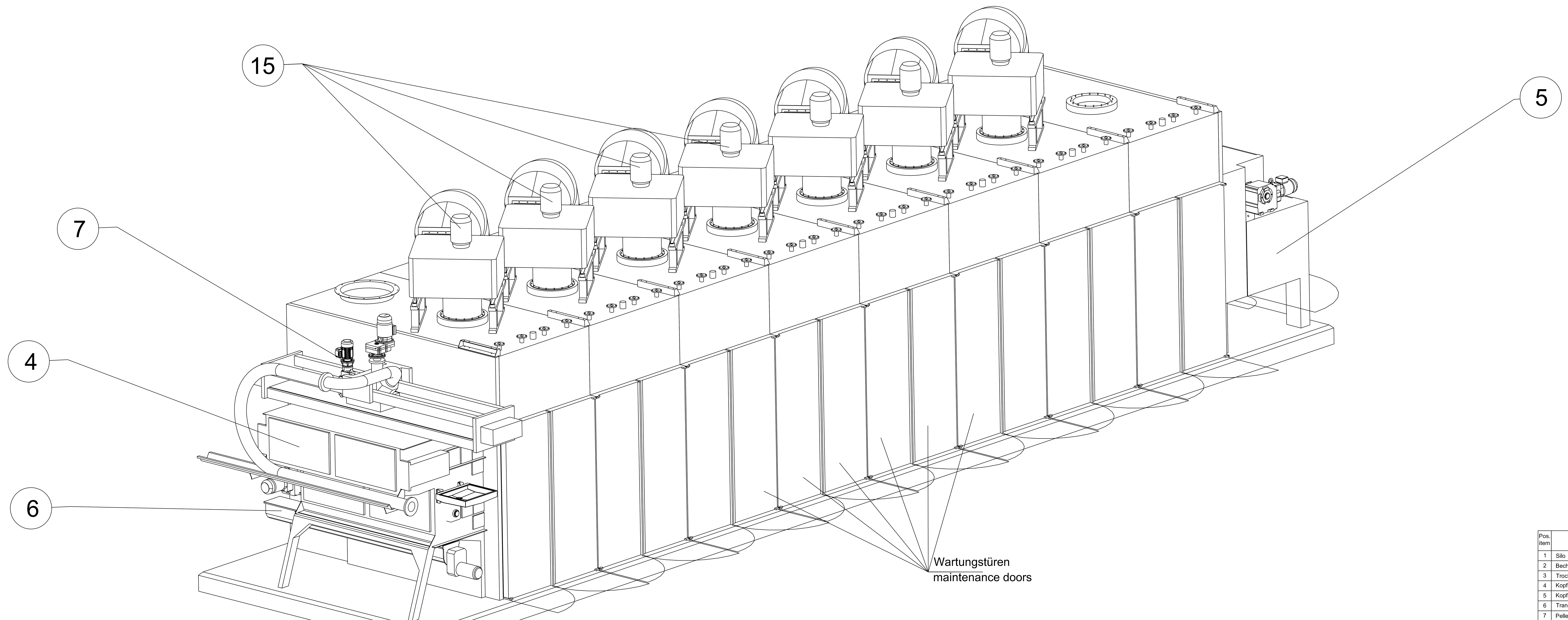
Massstab/Scale: 1:50

Trockner BT+ 16

dryer BT+ 16

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
000001_290270		5/7



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Massstab/Scale: 1:25

Trockner BT+ 16
dryer BT+ 16

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Projekt Project	Art.-Code Item Code	Blatt Sheet
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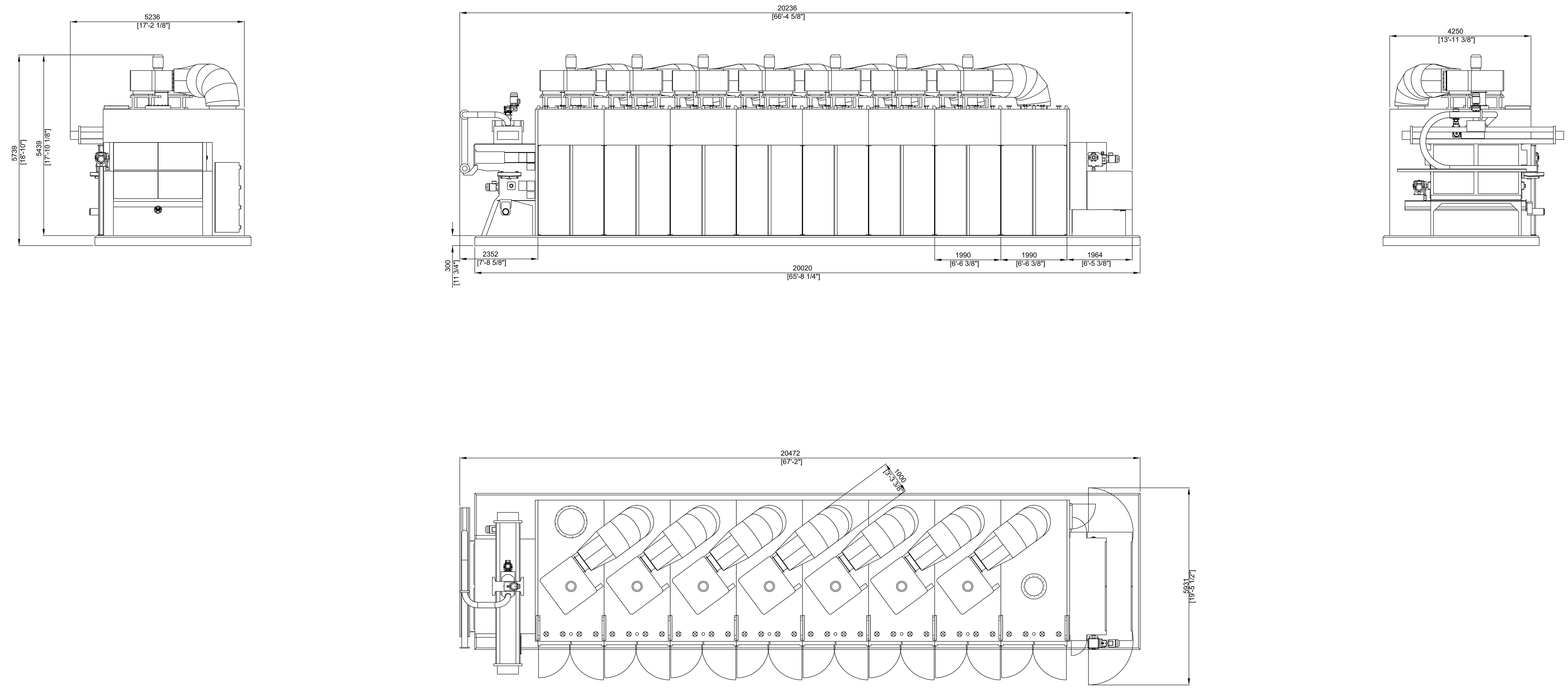

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Massstab/Scale: 1:50

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt / Project — Art.-Code / Item Code: 000001_290270 — Blatt / Sheet: 7/7

Huber Belt Dryer Proposal

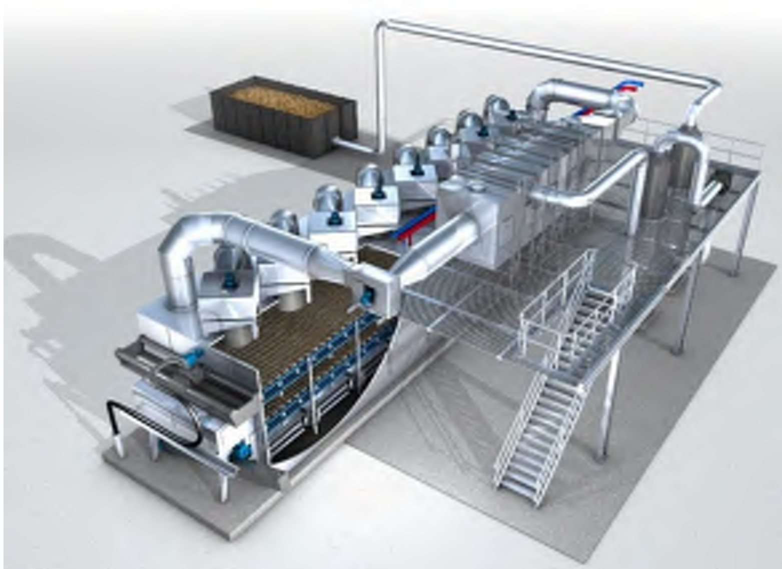
Current Conditions / No Digesters (3,175 dry tons per year)

Budgetary Proposal

Project Name:
Portsmouth, NH

Equipment Type:
BT 16 203°F
95°C

Proposal Date:
8/19/2019



Huber Contacts:
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Represented by:
Rich Russell
Walker-Wellington Associates
(603) 433-7497
rich@walkerwellington.com

HUBER TECHNOLOGY
WASTE WATER Solutions

Huber Technology, Inc.

9735 NorthCross Center Court
Suite A
Huntersville, NC 28078

Phone: (704) 949-1010
Fax: (704) 949-1020

Belt Dryer Design Summary

Portsmouth, NH August 19, 2019

Sludge Characteristics:

Upstream Process:	Information not provided
Digestion Process:	Information not provided
Sludge Type:	Unknown
Sludge VSS:	Information not provided
Sludge Protein Content:	Information not provided

Project Design Parameters:

Sludge Feed Rate:	3,176 dry ton/yr	(2,887 dry tonne/yr)
Sludge Feed Rate:	12,702 wet ton/yr	(11,547 wet tonne/yr)
Inlet Cake Concentration:	25%	
Calculated Sludge Loading Rate:	3,176 dry ton/yr	(2,887 dry tonne/yr)
Calculated Hydraulic Loading Rate (per unit):	12,702 wet ton/yr	(11,547 wet tonne/yr)

Equipment Recommendation:

Recommended unit model:	Huber Dryer BT 16	
Recommended unit quantity:	1	
<u>Project Design Calculations:</u>		
Estimated Dry Cake Solids Out:	92%	
Solids Loading Rate Out:	3,452 wet ton/year	(3,138 wet tonns/year)
Annual Water Evaporation Requirement:	9,250 ton water/year	(8,409 ton water/year)
Assumed Annual Operation Time:	6,240 hr/year	
Hourly Water Evaporation Requirement:	1.48 ton water/hr	(1.35 ton water/hr)
	2,965 lb water/hr	(1,345 kg water/hr)
<u>Equipment Design Parameters:</u>		
Thermal Heat Source:	Information Not Provided	
Estimated Heat Supply Temperature:	203°F (95°C)	

<u>Equipment Requirements:</u>

Heat Demand:	1,300 Btu/lb water evaporated
	3.85 MBtu/hr
	0.84 kWh/kg water evaporated
	1129 kW
Electrical Demand:	.03 kWh/lb water evaporated
	.07 kWh/kg water evaporated
	92 kW

Notes and Assumptions

Portsmouth, NH August 19, 2019

1. Equipment specification and drawings are available upon request.
2. If there are site-specific hydraulic constraints that must be applied, please consult the manufacturer's representative to ensure compatibility with the proposed system.
3. Huber Technology warrants all components of the system against faulty workmanship and materials for a period of 12 months from date of start-up or 18 months after shipment, whichever occurs first.
4. Budget estimate is based on Huber Technology's standard Terms & Conditions and is quoted in US dollars unless otherwise stated.
5. Equipment recommendations are based on information provided to Huber Technology. Subsequent information which differs from what has been provided may alter the equipment recommendation.
6. Pricing is based on Huber's standard control panel arrangement.

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Equipment Summary

Portsmouth, NH August 19, 2019

Dryer System:

One (1) Huber BT 16 Dryer, including:

- One (1) Belt
- Support Frame
- Belt Drive
- Belt Guides
- Drive Motor
- Tension Adjustors

Air Duct System:

- 304 Stainless Steel Materials
- Seven (7) Recirculation Air Ducts
- Fresh Air Inlet and Exhaust Air Outlet

Seven (7) Recirculating Fans:

- 304 Stainless Steel Materials
- Drive Motors

Air Ventilator

- 304 Stainless Steel Casing Material
- Drive Motor

Exhaust Fan:

- 304 Stainless Steel Casing Material
- Drive Motor

Heat Exchanger and Recovery System:

- Sixteen (16) Main Heat Exchangers
- Heat Recovery System including Heat Exchangers - 304 Stainless Steel

Outlet Conveyor:

- 304 Stainless Steel Materials
- Shafted Screw
- Drive Motor
- Carries Sludge to end of the dryer

Ancillary Equipment

- Control Panel with Allen Bradley PLC and HMI
- Allen Bradley MCC
- Live Bottom System with Feed Pump (approximately 100 yd^3)
  - Note: Size and Price Dependent on Final Design
  - Each Live Bottom will have two (2) feed pumps included
- Heat Recovery and Cleaning Pump
- Scrubber System

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• Dry Product Transport Conveyor
• Hot Water Boiler

Freight and Startup:

• Standard Huber Recommended Start-up Services
• Freight to jobsite.

Total Price: $ 3,700,000 (per unit)

Dryer Options

Portsmouth, NH August 19, 2019

Optional Items which can be supplied by Huber (but are not included in the above pricing):

Dry Product Storage Silo:

Dry Product Processing:

Items Not Supplied by Huber

Portsmouth, NH August 19, 2019

<u>Items not included in the above offering:</u>

- Wiring and Piping between all supplied equipment
- Installation
- Building structures
- Site Preparation
- Required maintenance platforms and cranes

Estimated Operational Cost

Thermal Energy Consumption		
Dyer Energy Usage	1,300 Btu/lb water evaporated	(0.840 kWh/kg water evaported)
Water Evaporation	2,965 lb water/hr	(1,345 kg water/hr)
Hourly Usage	3.85 MBtu/hr	(1,129 kW)
Assumed Operation	6,240 hr/year	

Natural Gas Cost

$12.00	/1000cuft *
1.037	MMBTU/1000cuf *
85%	Boiler Efficiency
$52.47	/hr
$327,428	/yr

Electrical Energy Consumption		
Dyer Energy Usage	0.03 kWh/lb water evaported	(0.07 kWh/kg water evaported)
Water Evaporation	2,965 lb water/hr	(1,345 kg water/hr)
Hourly Usage	91.91 kW	
Assumed Operation	6,240 hr/year	

Electrical Energy Cost

$0.16	/kWh **
$14.71	/hr
$91,764	/yr

*Thermal Energy Cost - Reference - Commercial Cost
https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PCS_DMcf_m.htm
https://www.eia.gov/tools/faqs/faq.php?id=45&t=8
**Electrical Energy Cost - Reference - Commercial Cost
https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

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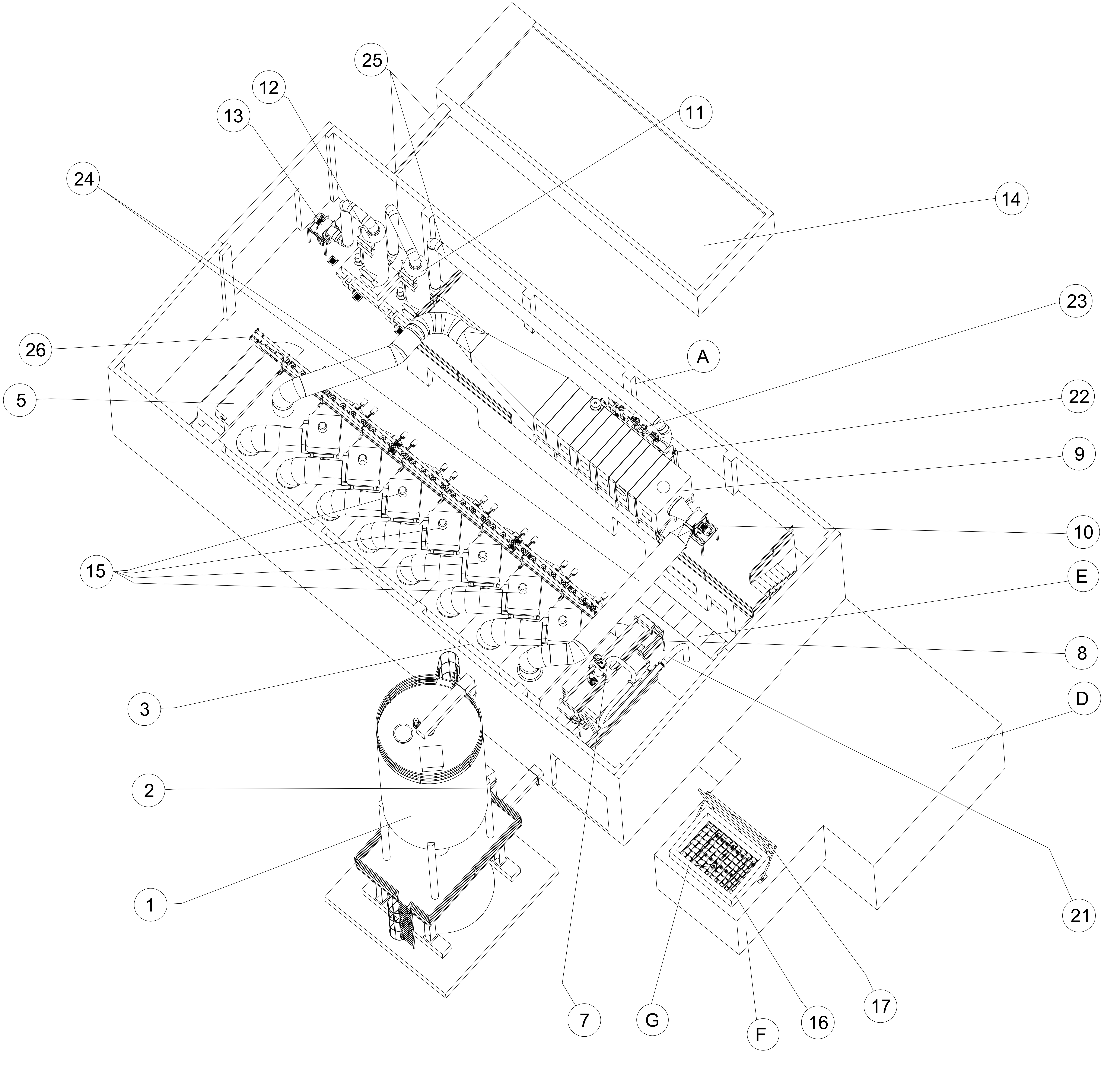

Pos. Item	Beschreibung	Description
A	Trocknerhalle	Dryerbuilding
B	Elektroschaltraum	Electrical Room
C	Auffangwane bodenbündig für Chemikalien	Collecting pan for chemicals
D	Wartungskeller	Maintenance cellar
E	Bergeöffnung	Maintenance opening
F	Nassschlammbunker	Wet sludge Storage
G	Einwurföffnung für Nassschlamm	Wet sludge acceptance
H	Chemikalienraum	Room for chemicals

Pos. Item	Bezeichnung	description
1	Silo	silo
2	Becherwerk	bucket chain conveyor
3	Trockner	dryer
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12	Luftwäscher basisch	scrubber alcaline/oxidizing
13	Fortluftventilator	exhaust fan
14	Biofilter	biofilter
15	Prozessluftventilator	process air fan
16	Einfallschutz	fall protection
17	Bunkerdeckel	hydraulik bunker cover
18	Schubboden	live bottom wet sludge
19	Hydraulikaggregat	hydraulic power unit
20	Dickschlammpumpe	wet sludge pump
21	Dickschlammleitung	wet sludge pipe
22	Waermerueckgewinnung	heat recovery system
23	Kühlwasserverrohrung	piping for cooling water
24	Lüftungsrohr Umluft	air pipe condensation air
25	Lüftungsrohr Fortluft	air pipe exhaust air
26	Heizungsverteiler	heating distribution

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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-	-	-	-	Gepr./Appr.	10.12.2013	hal
				Norm.		

Massstab/Scale: 1:50

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt / Project — Art.-Code / Item Code: 000001_290270 — Blatt / Sheet: 1/7

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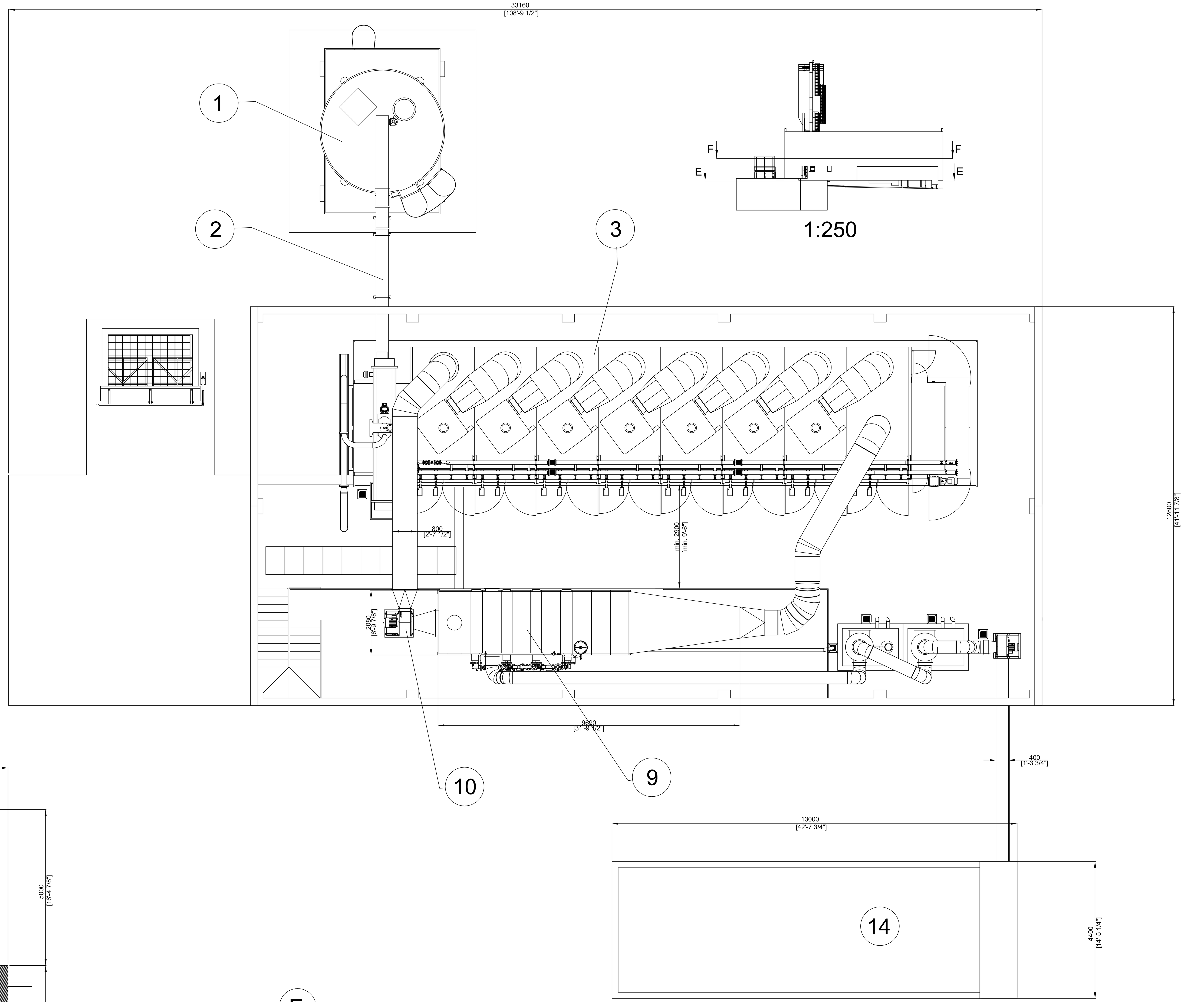

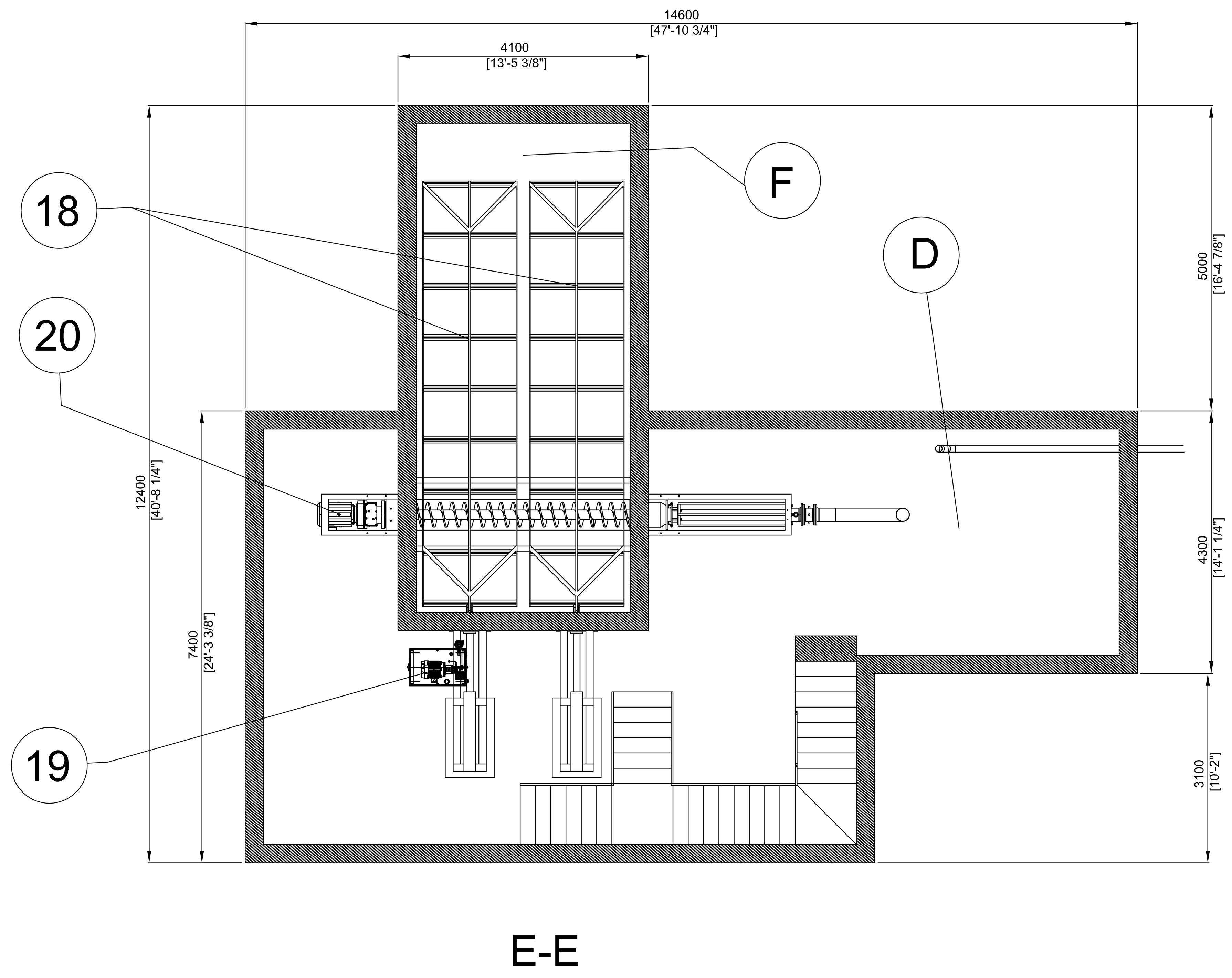

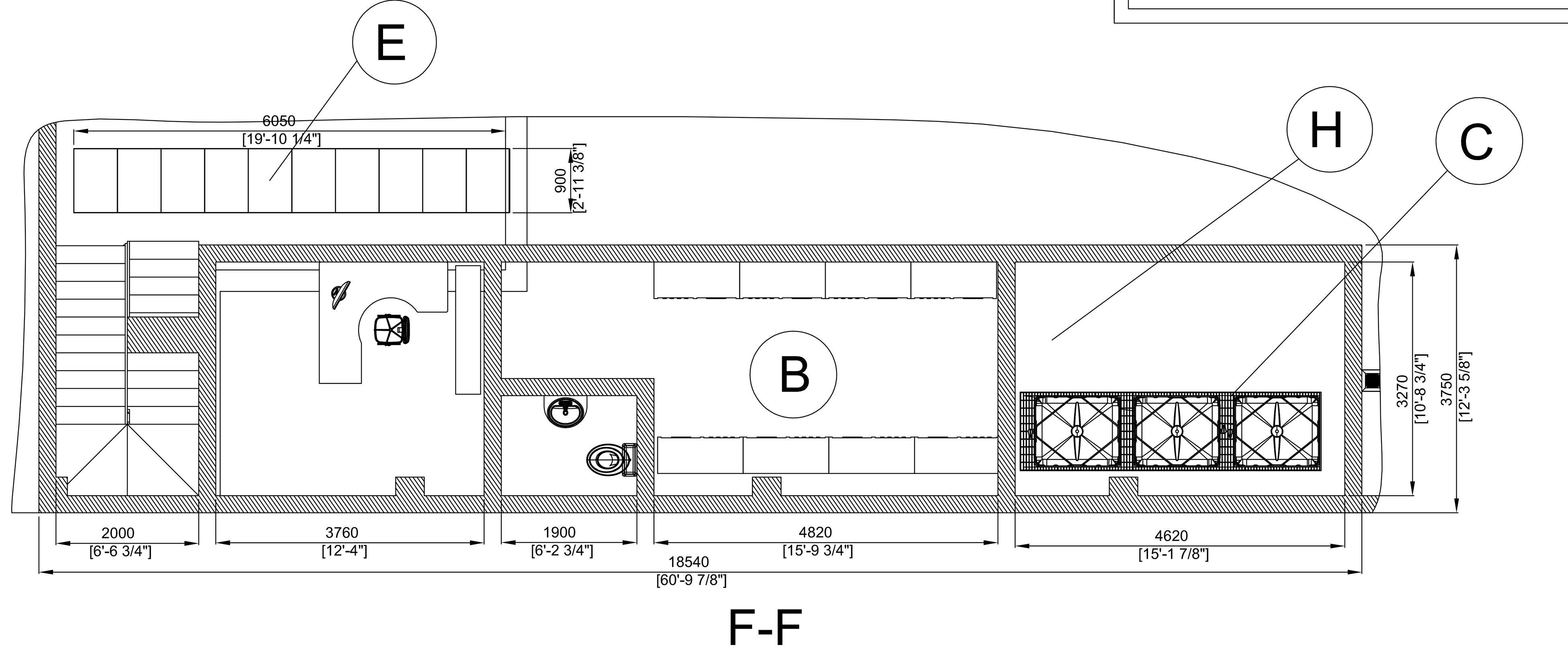

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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				Norm.		

Massstab/Scale: 1:50

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
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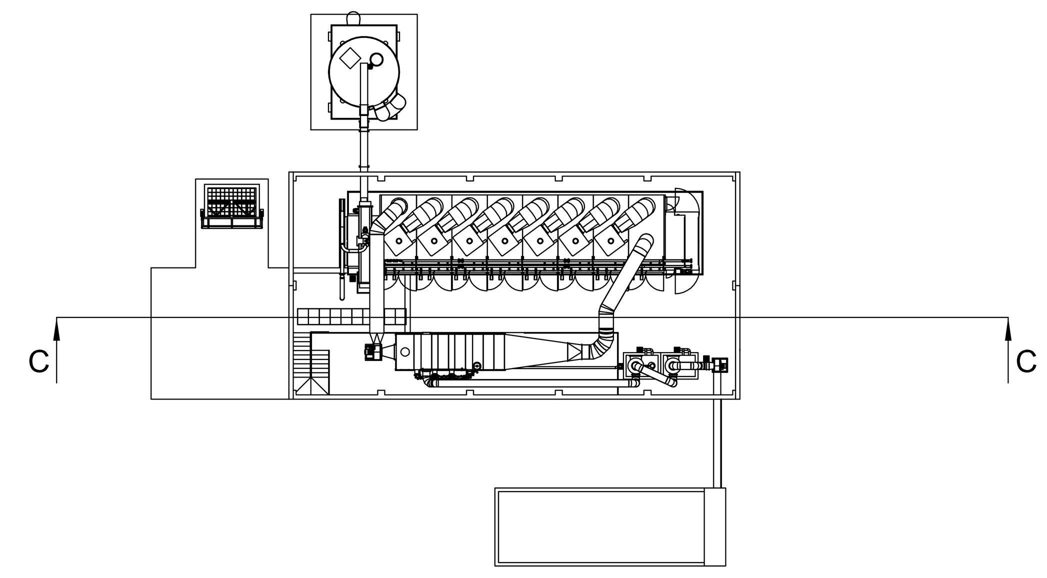

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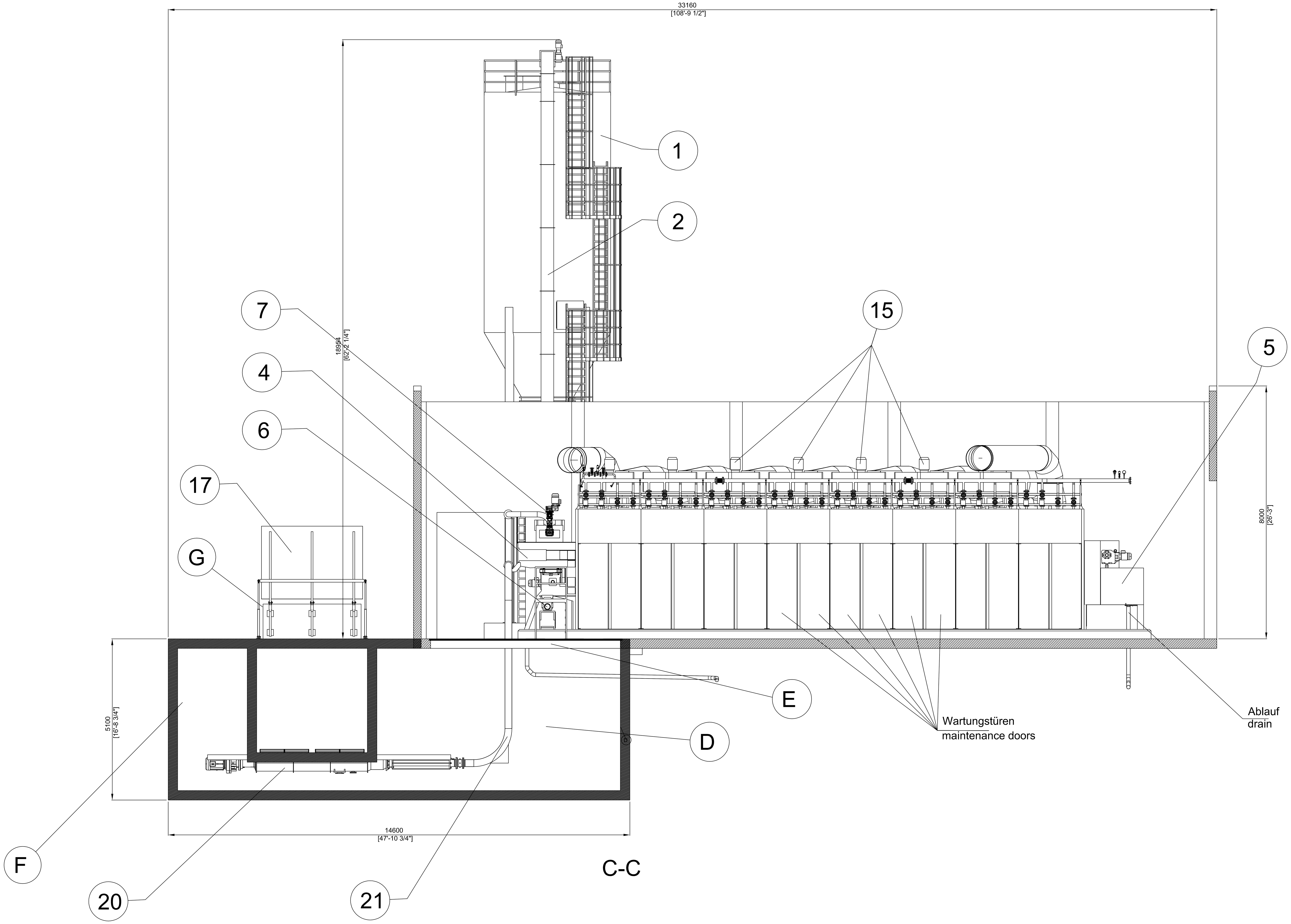

C-C

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22	Waermerueckgewinnung	heat recovery system
23	Kühlwasserverrohrung	piping for cooling water
24	Lüftungsrohr Umluft	air pipe condensation air
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Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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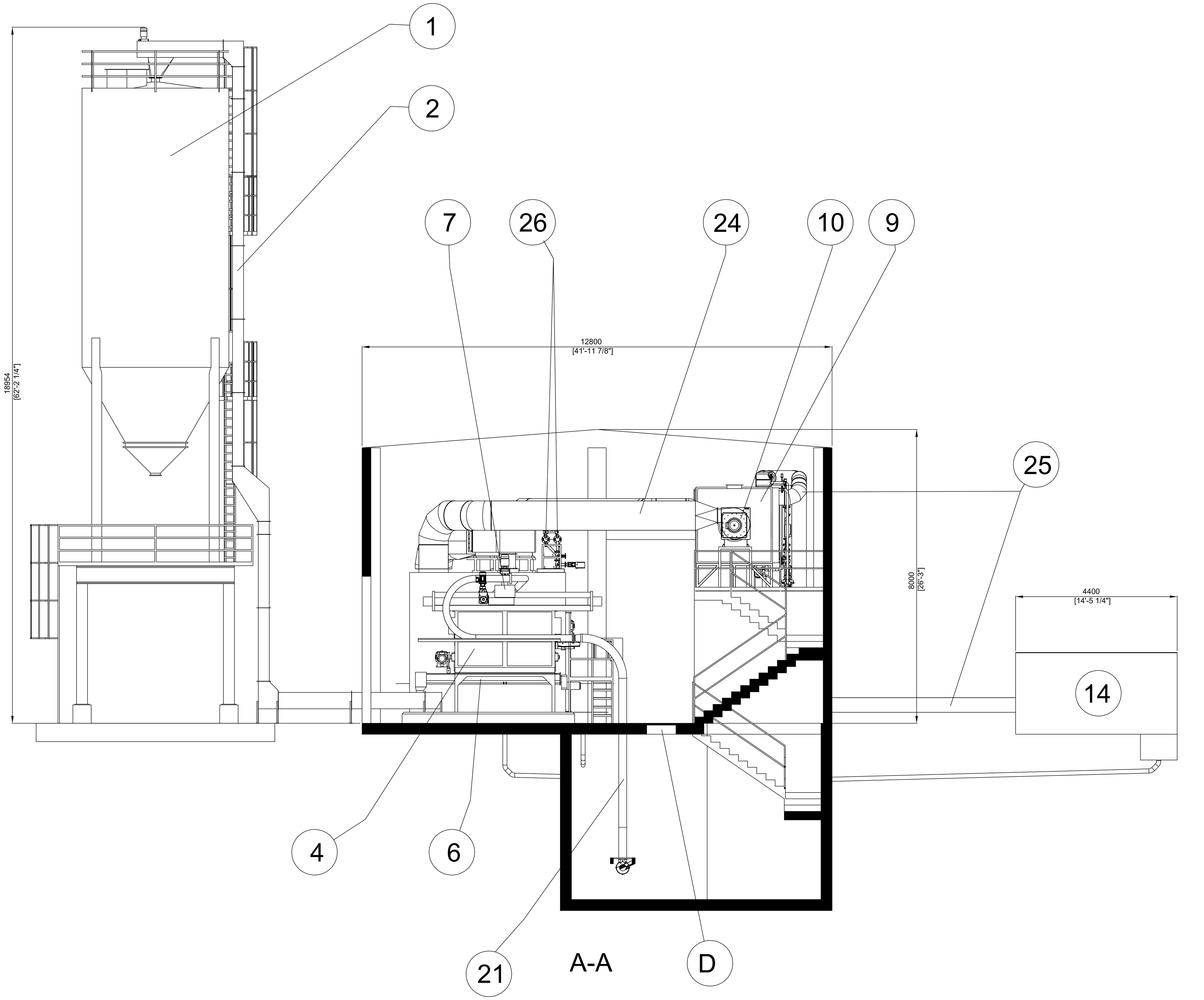
				Gepr./Appr.	10.12.2013	hal
				Norm.		

Massstab/Scale: 1:50

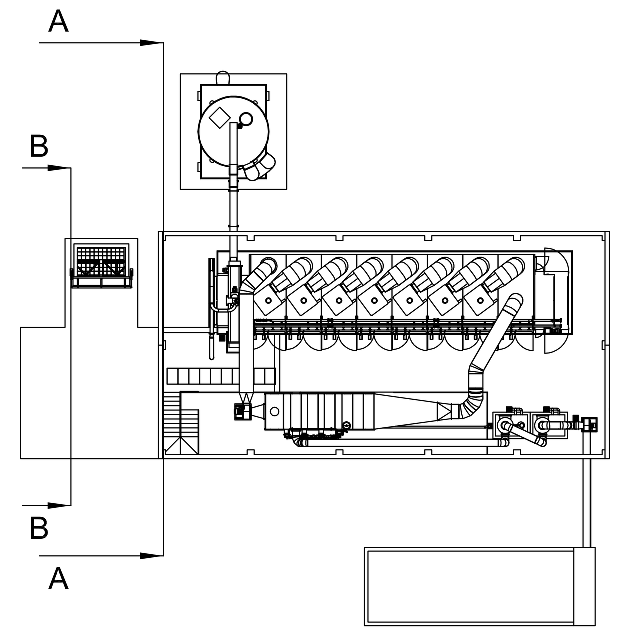
Trockner BT+ 16
dryer BT+ 16

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project | Art.-Code Item Code: 000001_290270 | Blatt Sheet: 3/7



A-A



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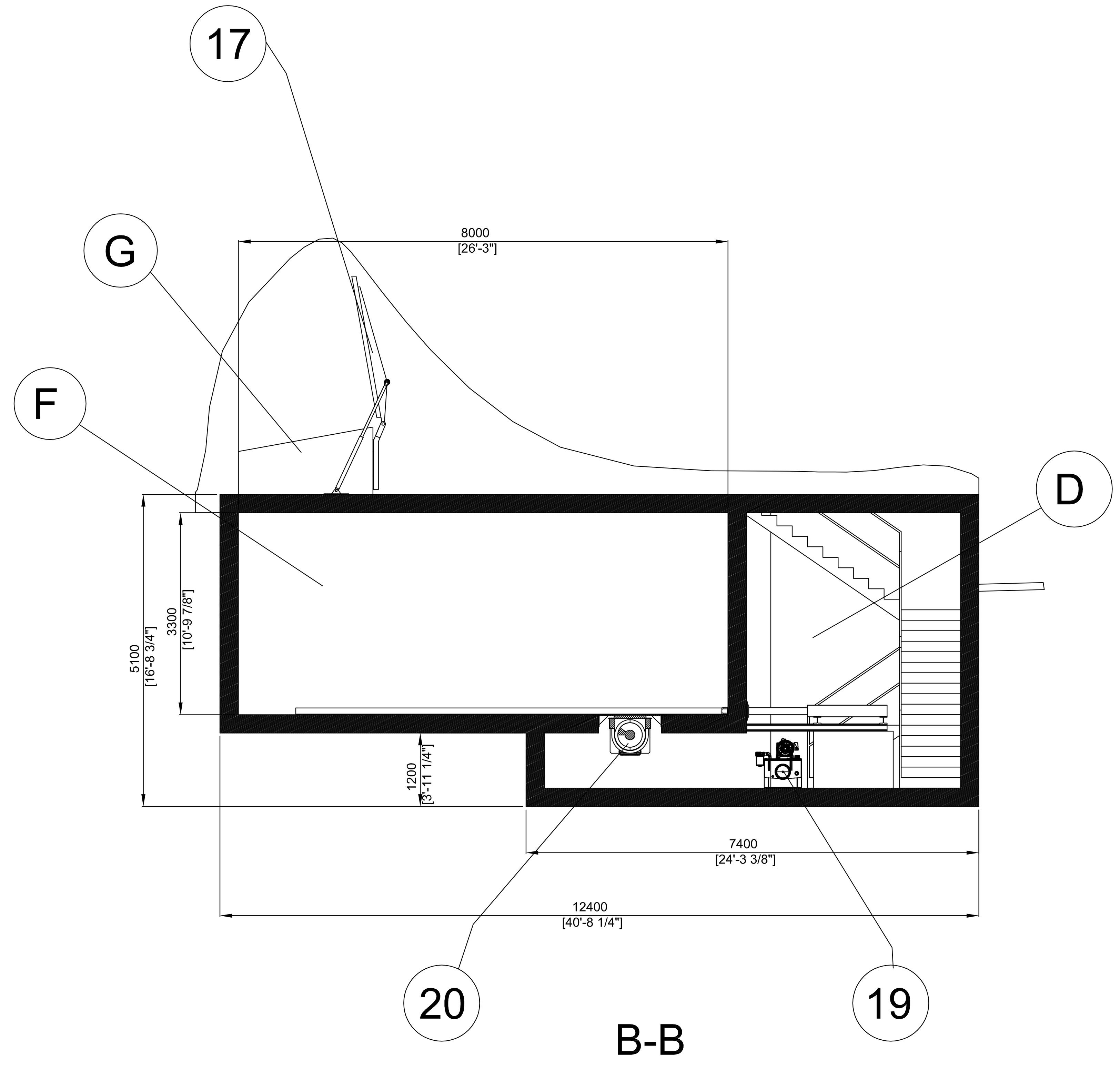

B-B

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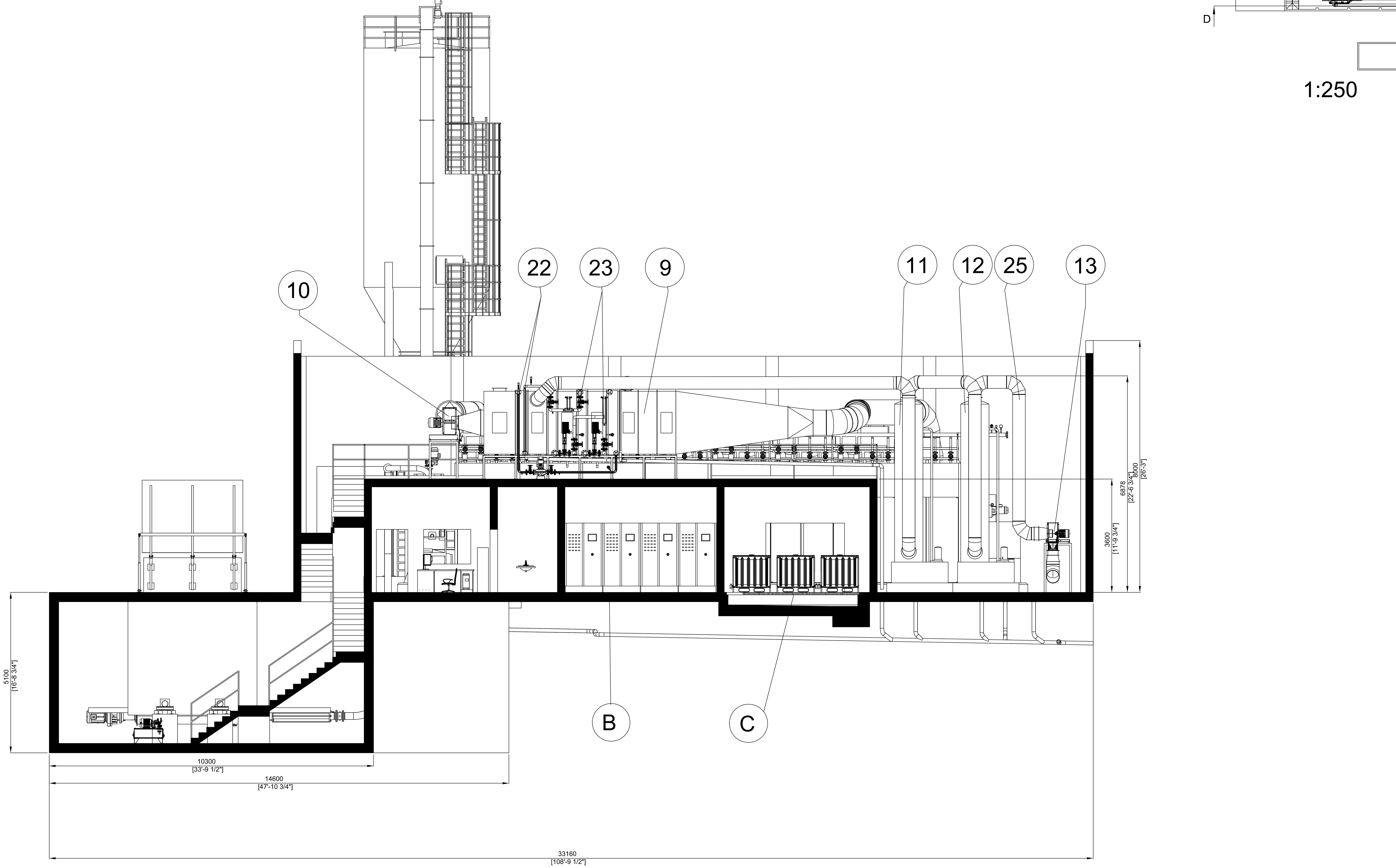
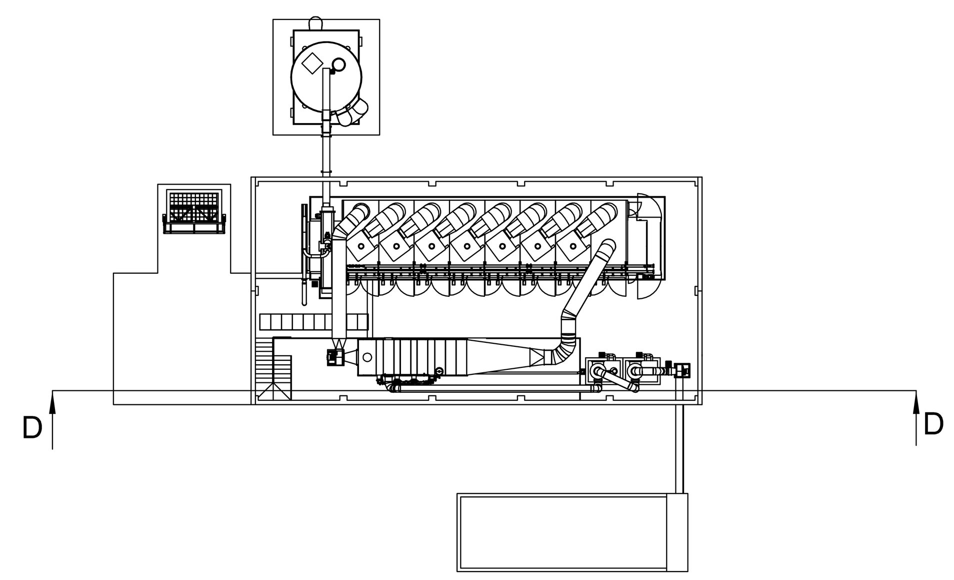
Massstab/Scale: 1:50

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
	000001_290270	4/7





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Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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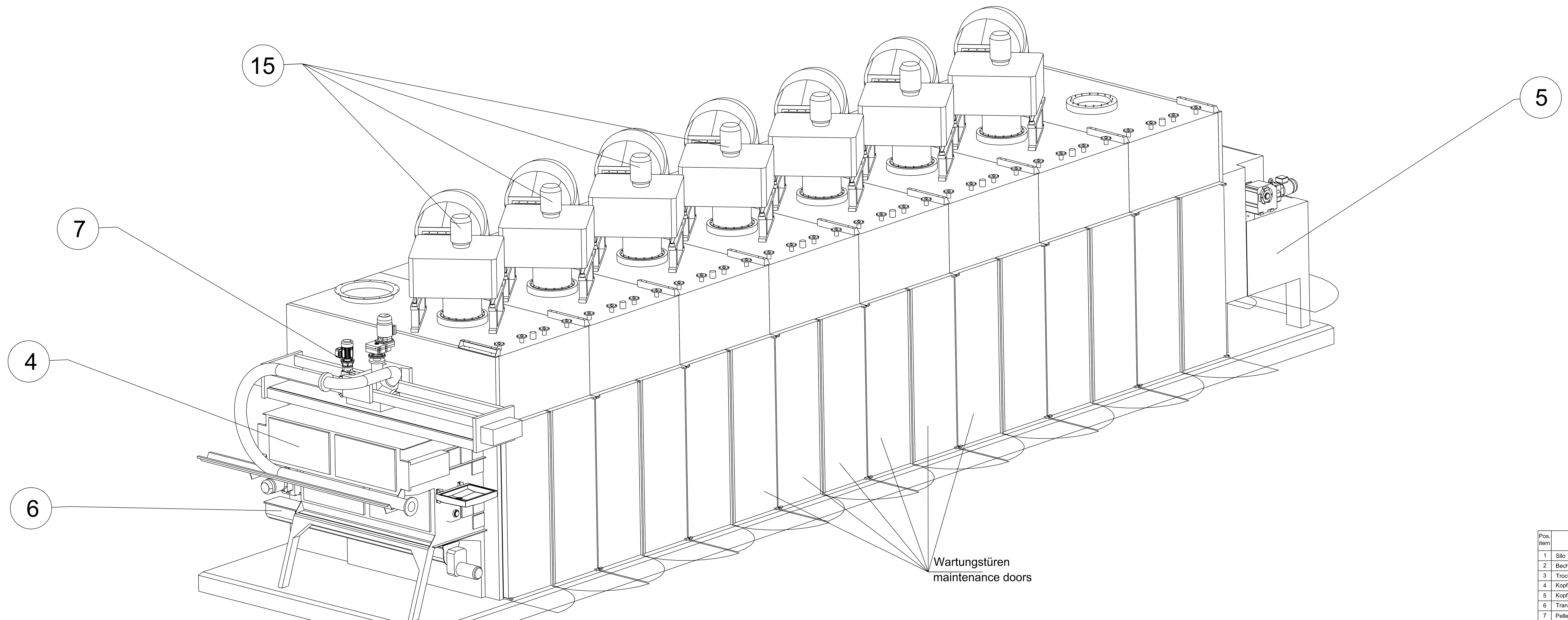
Massstab/Scale: 1:50

Trockner BT+ 16

dryer BT+ 16

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
000001_290270		5/7



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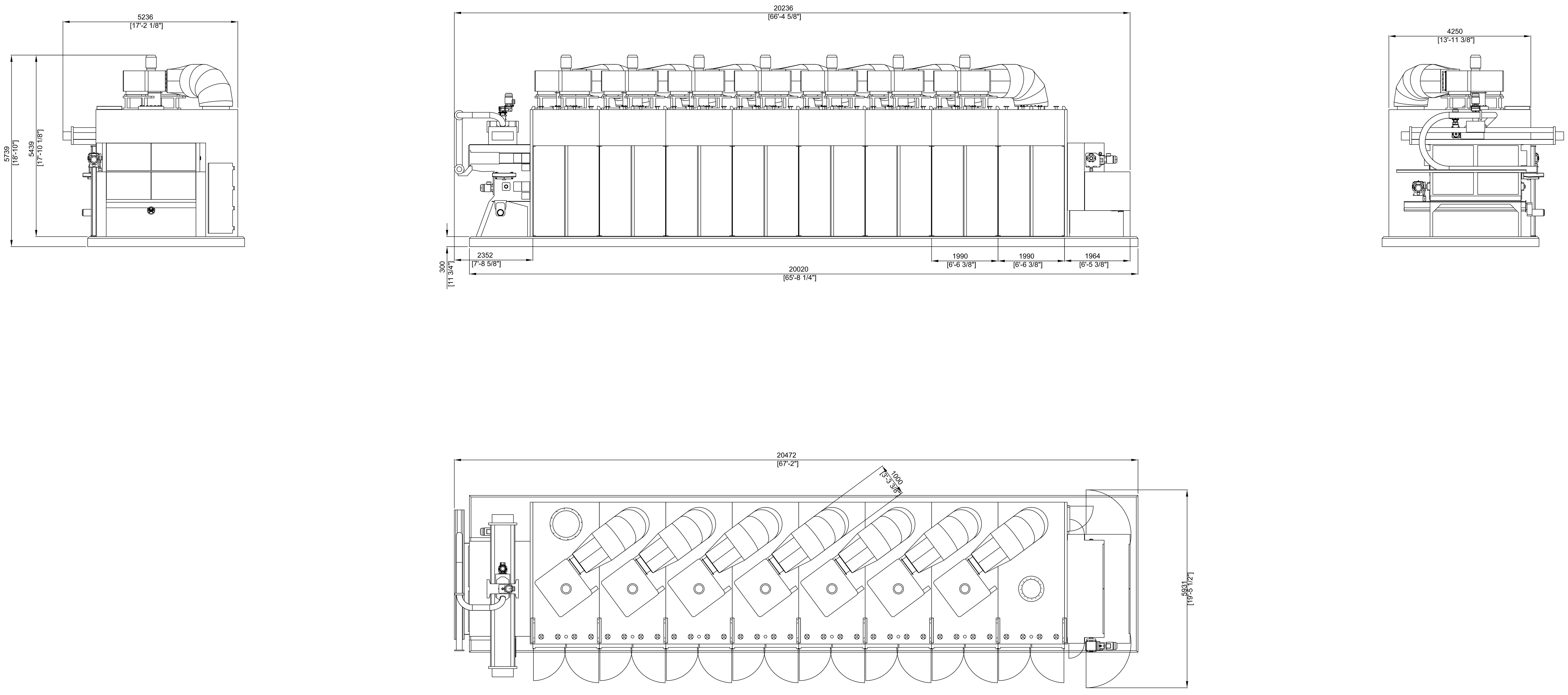
-	-	-	-	Gepr./Appr.	10.12.2013	hal
				Norm.		

Massstab/Scale: 1:25

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
000001_290270		6/7



Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
-	-	---	---	

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Technische Aenderungen vorbehalten / Subject to change — ISO 2768-mK

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Revision	Aenderung Modified	Tag Date	Name		Datum/Date	Name
				Bear./Rev.	10.12.2013	kep
-	-	-	-	Gepr./Appr.	10.12.2013	hal
				Norm.		

Massstab/Scale: 1:50

Trockner BT+ 16
dryer BT+ 16

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
000001_290270		7/7

Huber Belt Dryer Proposal

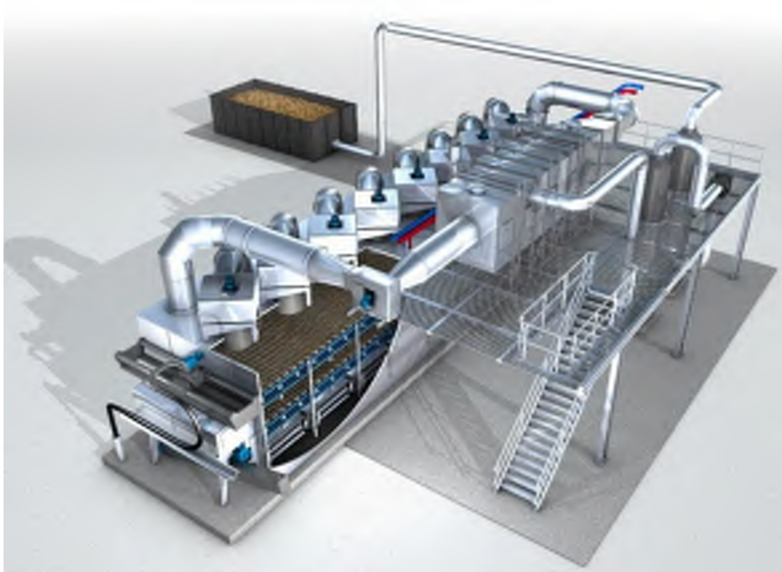
RBPF (5,800 dry tons per year)

Budgetary Proposal

Project Name:
Portsmouth, NH

Equipment Type:
BT 24 203°F
95°C

Proposal Date:
6/24/2019



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Represented by:
Rich Russell
Walker-Wellington Associates
(603) 433-7497
rich@walkerwellington.com

HUBER TECHNOLOGY
WASTE WATER Solutions

Huber Technology, Inc.

9735 NorthCross Center Court
Suite A
Huntersville, NC 28078

Phone: (704) 949-1010
Fax: (704) 949-1020

Belt Dryer Design Summary

Portsmouth, NH June 24, 2019

Sludge Characteristics:

Upstream Process:	Information not provided
Digestion Process:	Information not provided
Sludge Type:	Unknown
Sludge VSS:	Information not provided
Sludge Protein Content:	Information not provided

Project Design Parameters:

Sludge Feed Rate:	6,160 dry ton/yr	(5,600 dry tonne/yr)
Sludge Feed Rate:	25,667 wet ton/yr	(23,334 wet tonne/yr)
Inlet Cake Concentration:	24%	
Calculated Sludge Loading Rate:	6,160 dry ton/yr	(5,600 dry tonne/yr)
Calculated Hydraulic Loading Rate (per unit):	25,667 wet ton/yr	(23,334 wet tonne/yr)

Equipment Recommendation:

Recommended unit model:	Huber Dryer BT 24	
Recommended unit quantity:	1	
Project Design Calculations:		
Estimated Dry Cake Solids Out:	92%	
Solids Loading Rate Out:	6,696 wet ton/year	(6,087 wet tonns/year)
Annual Water Evaporation Requirement:	18,971 ton water/year	(17,247 ton water/year)
Assumed Annual Operation Time:	8,000 hr/year	
Hourly Water Evaporation Requirement:	2.37 ton water/hr	(2.16 ton water/hr)
	4,743 lb water/hr	(2,151 kg water/hr)
Equipment Design Parameters:		
Thermal Heat Source:	Information Not Provided	
Estimated Heat Supply Temperature:	203°F (95°C)	

Equipment Requirements:

Heat Demand:	1,300 Btu/lb water evaporated
	6.17 MBtu/hr
	0.84 kWh/kg water evaporated
	1807 kW
Electrical Demand:	.03 kWh/lb water evaporated
	.07 kWh/kg water evaporated
	147 kW

HUBER Technology, Inc.
Huber Technology, Inc. · 9735 NorthCross Center Court STE A · Huntersville, NC 28078
Phone (704) 949-1010 · Fax (704) 949-1020 · huber@hhusa.net · www.huber-technology.com
A member of the HUBER Group

Notes and Assumptions

Portsmouth, NH   June 24, 2019

1. Equipment specification and drawings are available upon request.
2. If there are site-specific hydraulic constraints that must be applied, please consult the manufacturer's representative to ensure compatibility with the proposed system.
3. Huber Technology warrants all components of the system against faulty workmanship and materials for a period of 12 months from date of start-up or 18 months after shipment, whichever occurs first.
4. Budget estimate is based on Huber Technology's standard Terms & Conditions and is quoted in US dollars unless otherwise stated.
5. Equipment recommendations are based on information provided to Huber Technology. Subsequent information which differs from what has been provided may alter the equipment recommendation.
6. Pricing is based on Huber's standard control panel arrangement.

7 180yd^3 hopper is estimated. Design and pricing would have to be confirmed with a hopper manufacturer. Design might be better suited for multiple Hoppers.

Equipment Summary

Portsmouth, NH June 24, 2019

<u>Dryer System:</u>

One (1) Huber BT 24 Dryer, including:

- One (1) Belt
- Support Frame
- Belt Drive
- Belt Guides
- Drive Motor
- Tension Adjustors

Air Duct System:

- 304 Stainless Steel Materials
- Eleven (11) Recirculation Air Ducts
- Fresh Air Inlet and Exhaust Air Outlet

Eleven (11) Recirculating Fans:

- 304 Stainless Steel Materials
- Drive Motors

Air Ventilator

- 304 Stainless Steel Casing Material
- Drive Motor

Exhaust Fan:

- 304 Stainless Steel Casing Material
- Drive Motor

Heat Exchanger and Recovery System:

- Twenty four (24) Main Heat Exchangers
- Heat Recovery System including Heat Exchangers - 304 Stainless Steel

Outlet Conveyor:

- 304 Stainless Steel Materials
- Shafted Screw
- Drive Motor
- Carries Sludge to end of the dryer

<u>Ancillary Equipment</u>

- Control Panel with Allen Bradley PLC and HMI
- Allen Bradley MCC
- Live Bottom System with Feed Pump (approximately 180 yd^3* - See note 7)
    - Note: Size and Price Dependent on Final Design
    - Each Live Bottom will have two (2) feed pumps included
- Heat Recovery and Cleaning Pump
- Scrubber System

- Dry Product Transport Conveyor
- Hot Water Boiler

Freight and Startup:

- Standard Huber Recommended Start-up Services
- Freight to jobsite.

Total Price: $ 5,400,000 (per unit)

Dryer Options

Portsmouth, NH June 24, 2019

Optional Items which can be supplied by Huber (but are not included in the above pricing):

Dry Product Storage Silo:

Dry Product Processing:

Items Not Supplied by Huber

Portsmouth, NH June 24, 2019

<u>Items not included in the above offering:</u>

- Wiring and Piping between all supplied equipment
- Installation
- Building structures
- Site Preparation
- Required maintenance platforms and cranes

Estimated Operational Cost

Thermal Energy Consumption

Dyer Energy Usage	1,300 Btu/lb water evaporated	(0.840 kWh/kg water evaported)
Water Evaporation	4,743 lb water/hr	(2,151 kg water/hr)
Hourly Usage	6.17 MBtu/hr	(1,807 kW)
Assumed Operation	8,000 hr/year	

Natural Gas Cost

$12.00	/1000cuft *
1.037	MMBTU/1000cuf *
85%	Boiler Efficiency
$83.94	/hr
$671,516	/yr

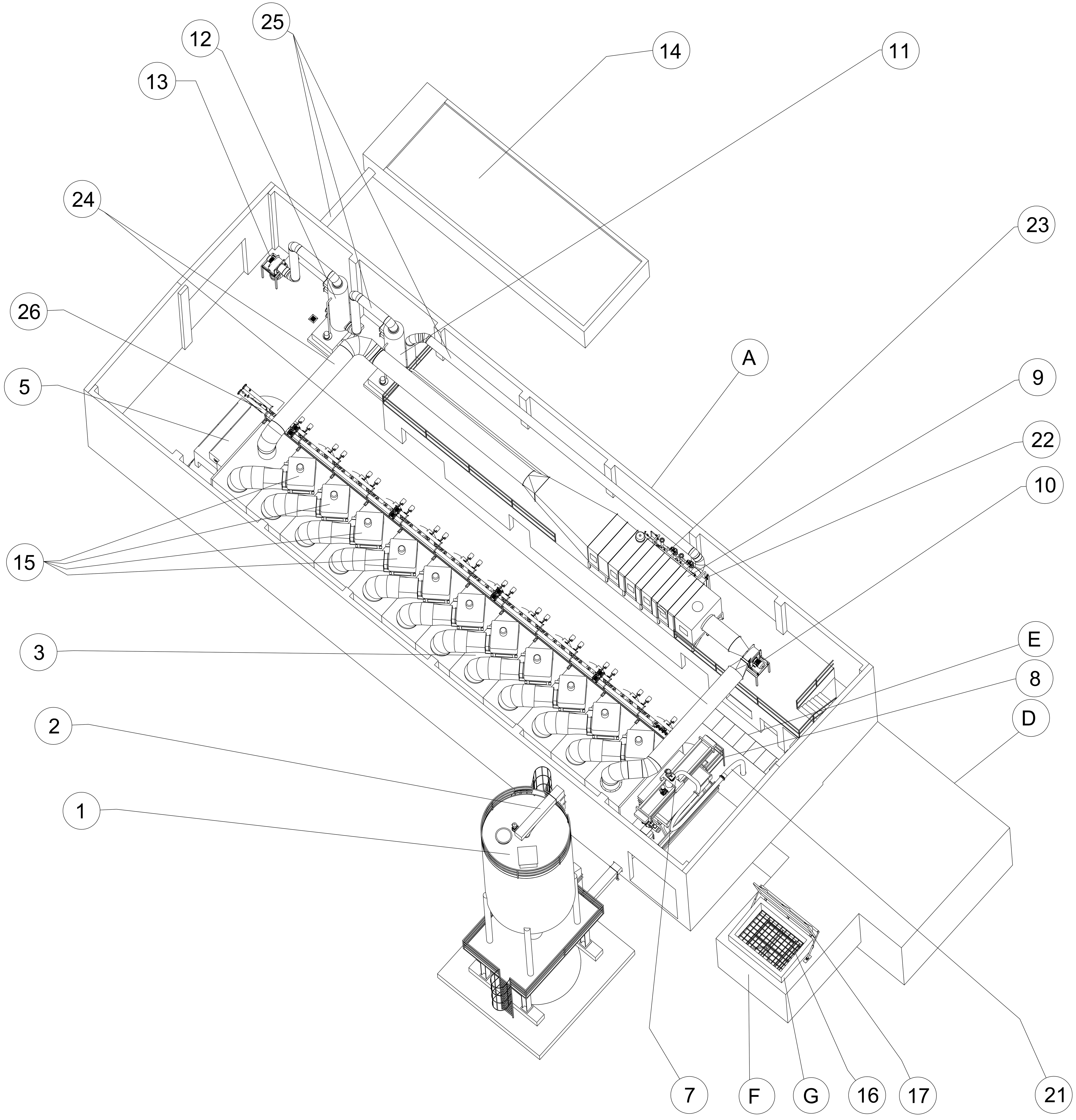
Electrical Energy Consumption

Dyer Energy Usage	0.03 kWh/lb water evaported	(0.07 kWh/kg water evaported)
Water Evaporation	4,743 lb water/hr	(2,151 kg water/hr)
Hourly Usage	147.03 kW	
Assumed Operation	8,000 hr/year	

Electrical Energy Cost

$0.16	/kWh **
$23.52	/hr
$188,196	/yr

*Thermal Energy Cost - Reference - Commercial Cost
https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PCS_DMcf_m.htm
https://www.eia.gov/tools/faqs/faq.php?id=45&t=8
**Electrical Energy Cost - Reference - Commercial Cost
https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a



Pos. Item	Beschreibung	Description
A	Trocknerhalle	Dryerbuilding
B	Elektroschaltraum	Electrical Room
C	Auffangwane bodenbündig für Chemikalien	Collecting pan for chemicals
D	Wartungskeller	Maintenance cellar
E	Bergeöffnung	Maintenance opening
F	Nassschlammbunker	Wet sludge Storage
G	Einwurföffnung für Nassschlamm	Wet sludge acceptance
H	Chemikalienraum	Room for chemicals
I	Lagerraum	Storage room

Pos. Item	Bezeichnung	description
1	Silo	silo
2	Becherwerk	bucket chain conveyor
3	Trockner	dryer
4	Kopfstück 1	head end 1
5	Kopfstück 2	head end 2
6	Transportschnecke RoßT	screw conveyor RoßT
7	Pelletierer	pellet former
8	Wartungsbuehne	maintenance platform
9	Kondensationsstufe	condensation unit
10	Ventilator für Kondensationsstufe	fan for condensation unit
11	Luftwäscher sauer	scrubber acid
12	Luftwäscher basisch	scrubber alcaline/oxidizing
13	Fortluftventilator	exhaust fan
14	Biofilter	biofilter
15	Prozessluftventilator	process air fan
16	Einfallschutz	fall protection
17	Bunkerdeckel	hydraulik bunker cover
18	Schubboden	live bottom wet sludge
19	Hydraulikaggregat	hydraulic power unit
20	Dickschlammpumpe	wet sludge pump
21	Dickschlammleitung	wet sludge pipe
22	Waermerueckgewinnung	heat recovery system
23	Kühlwasserverrohrung	piping for cooling water
24	Lüftungsrohr Umluft	air pipe condensation air
25	Lüftungsrohr Fortluft	air pipe exhaust air
26	Heizungsverteiler	heating distribution

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
-	-			

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	Datum/Date	Name
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Gepr./Appr.	30.10.2013	hal
Norm.		

Revision: - | Aenderung Modified: - | Tag Date: - | Name: -

Massstab/Scale: 3:200

Trockner BT+ 24
dryer BT+ 24

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project / Art.-Code Item Code: 000001_290247 — Blatt Sheet: 1/7

Pos. Item	Beschreibung	Description
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B	Elektroschaltraum	Electrical Room
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24	Lüftungsrohr Umluft	air pipe condensation air
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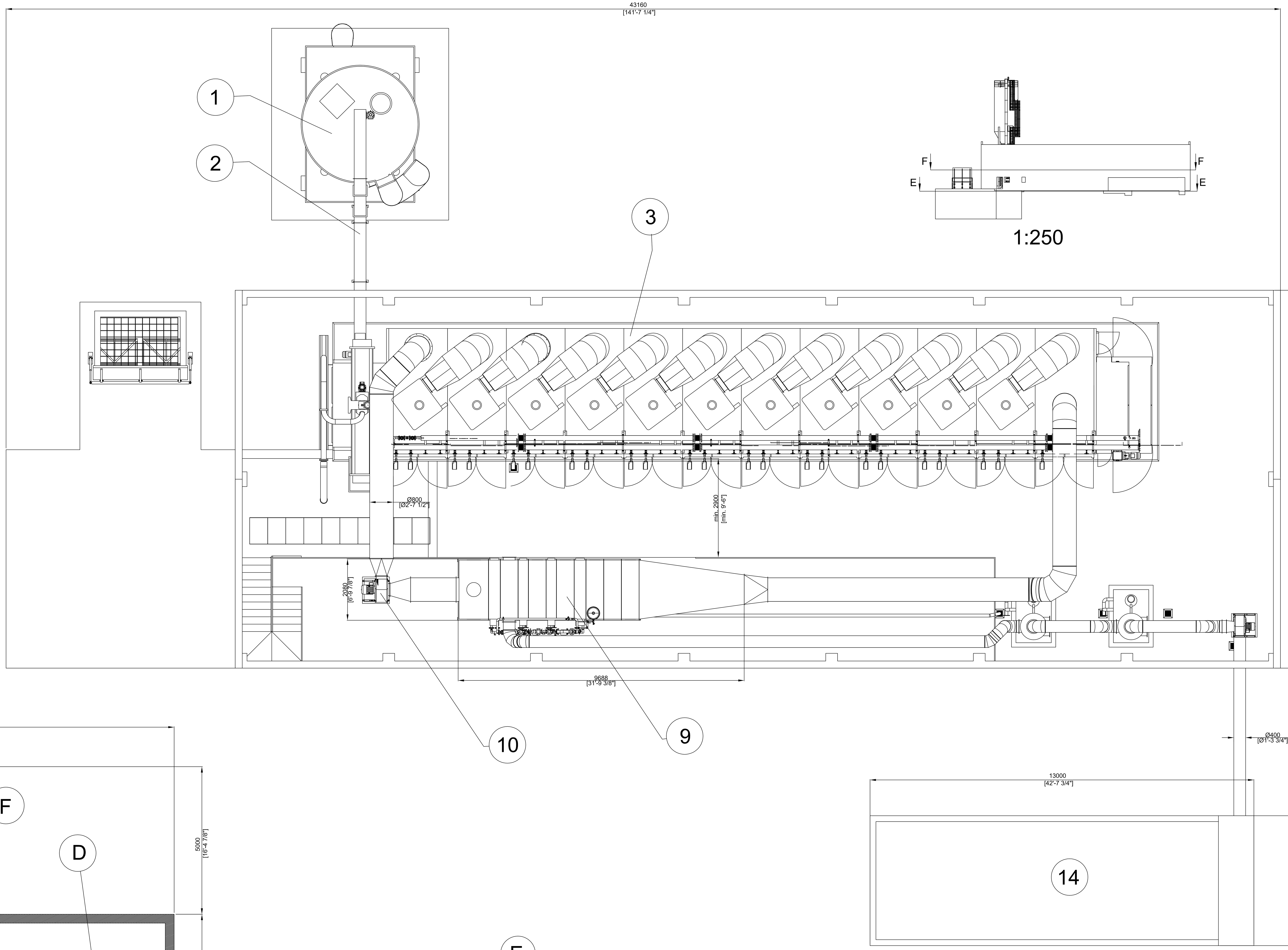
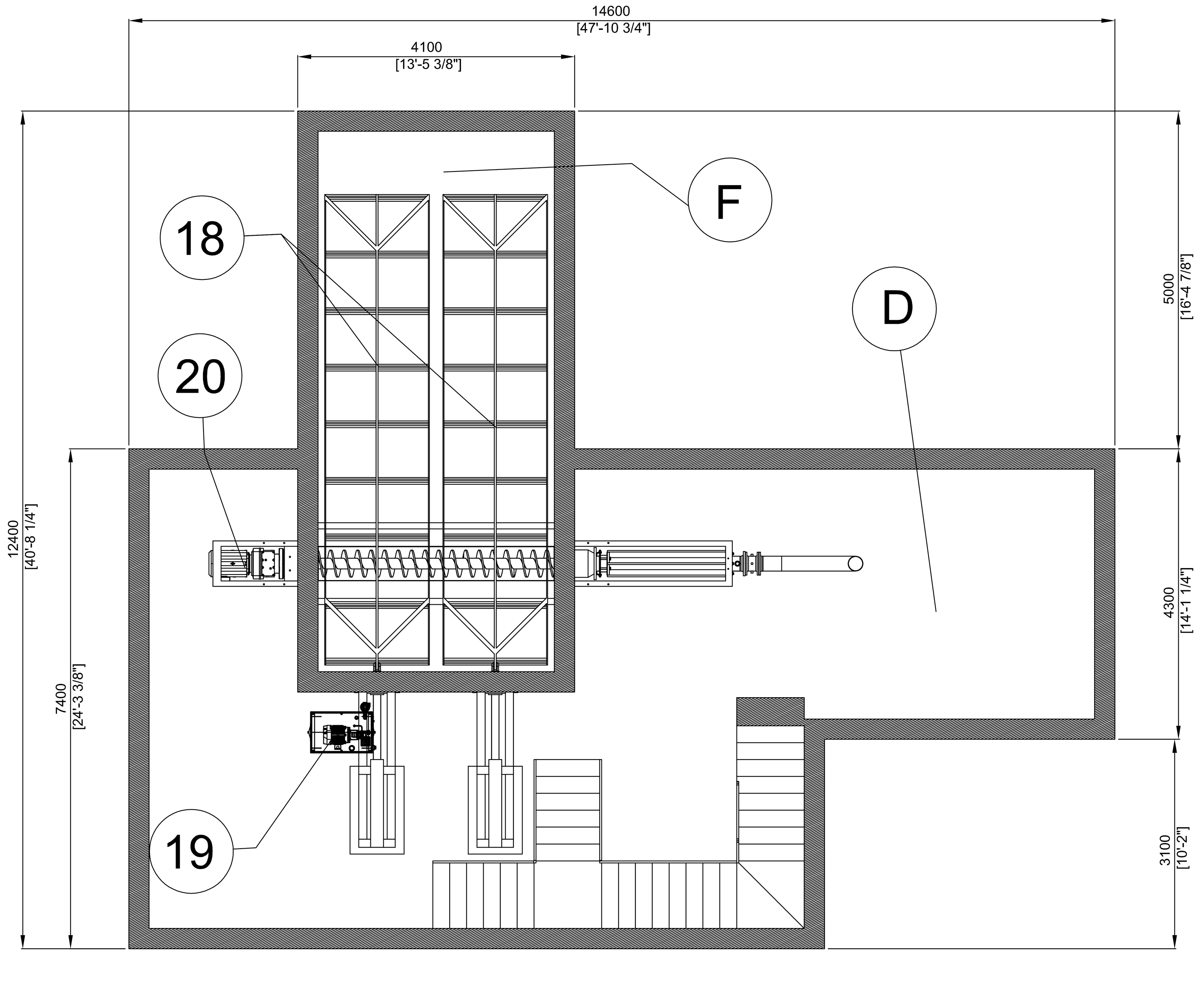
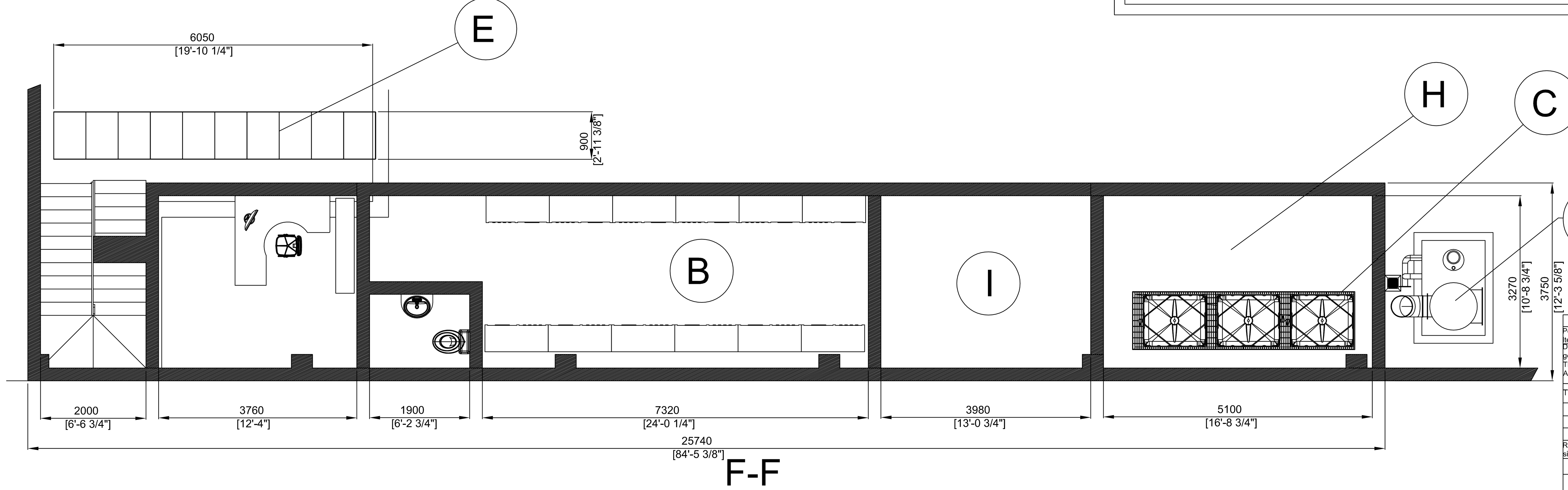
26	Heizungsverteiler	heating distribution







Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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Technische Aenderungen vorbehalten / Subject to change — ISO 2768-mK

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Revision	Aenderung Modified	Tag Date	Name		Datum/Date	Name
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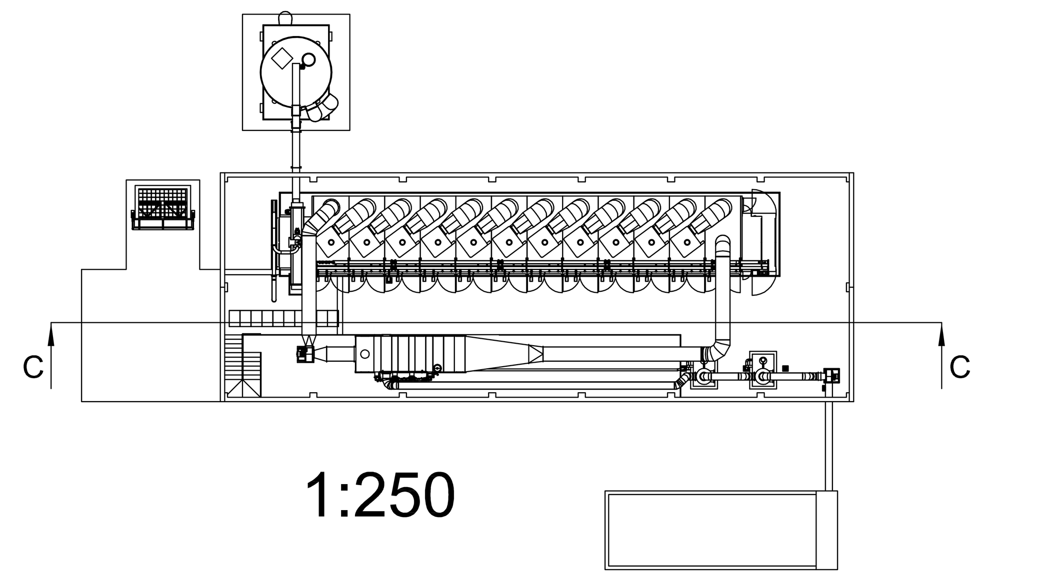
-	-	-	-	Gepr./Appr.	23.07.2013	kep
				Norm.		
				Massstab/Scale: 1:50		

Trockner BT+ 24

dryer BT+ 24

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project — Art.-Code Item Code: 000001_290247 — Blatt Sheet: 2/7



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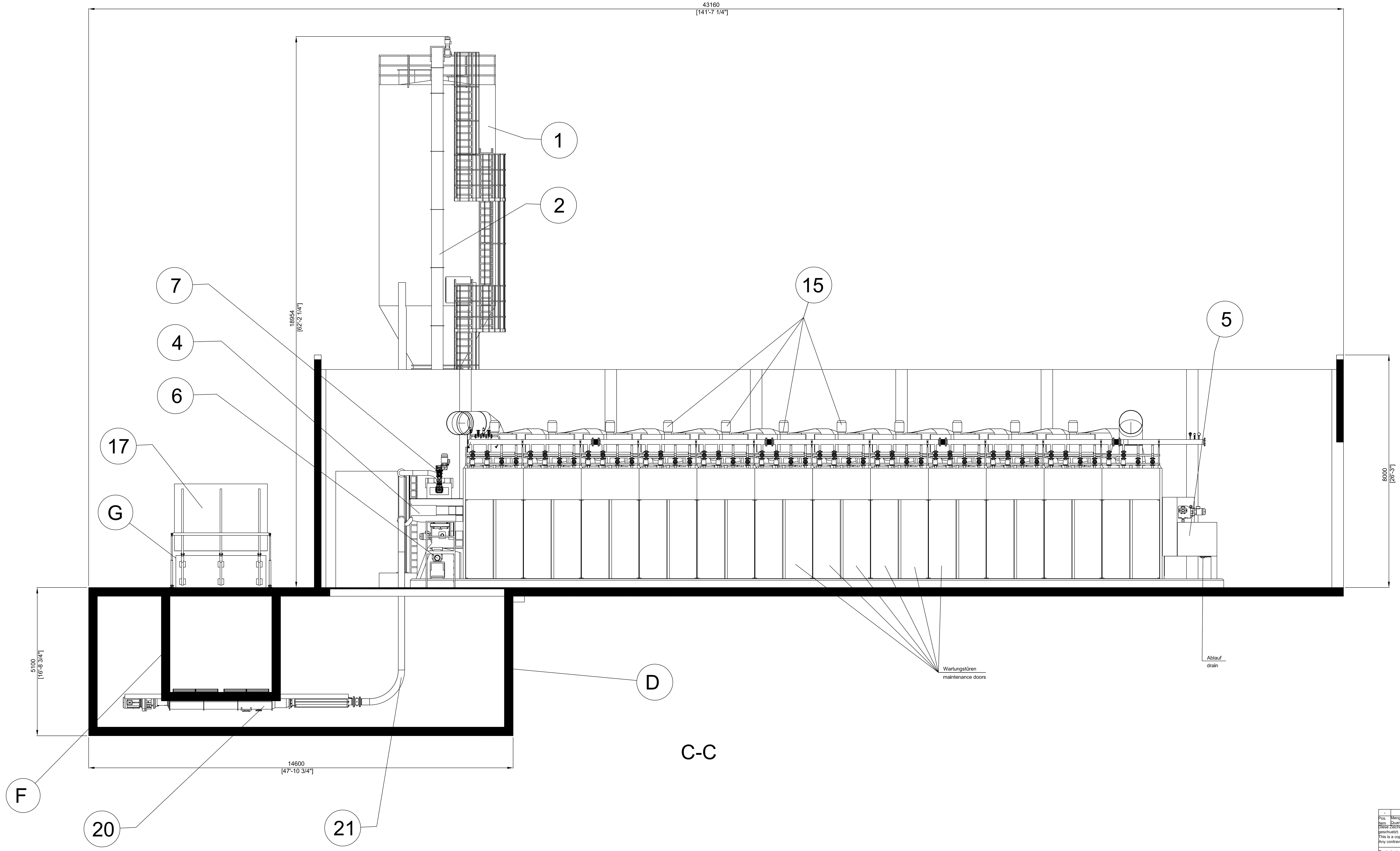

C-C

Pos. Item	Beschreibung	Description
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Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
-	-	------------------------------ ----------------	-------------	

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Technische Aenderungen vorbehalten / Subject to change

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				Bear./Rev.	10.10.2013	kep
-	-	-	-	Gepr./Appr.	30.10.2013	hal
				Norm.		

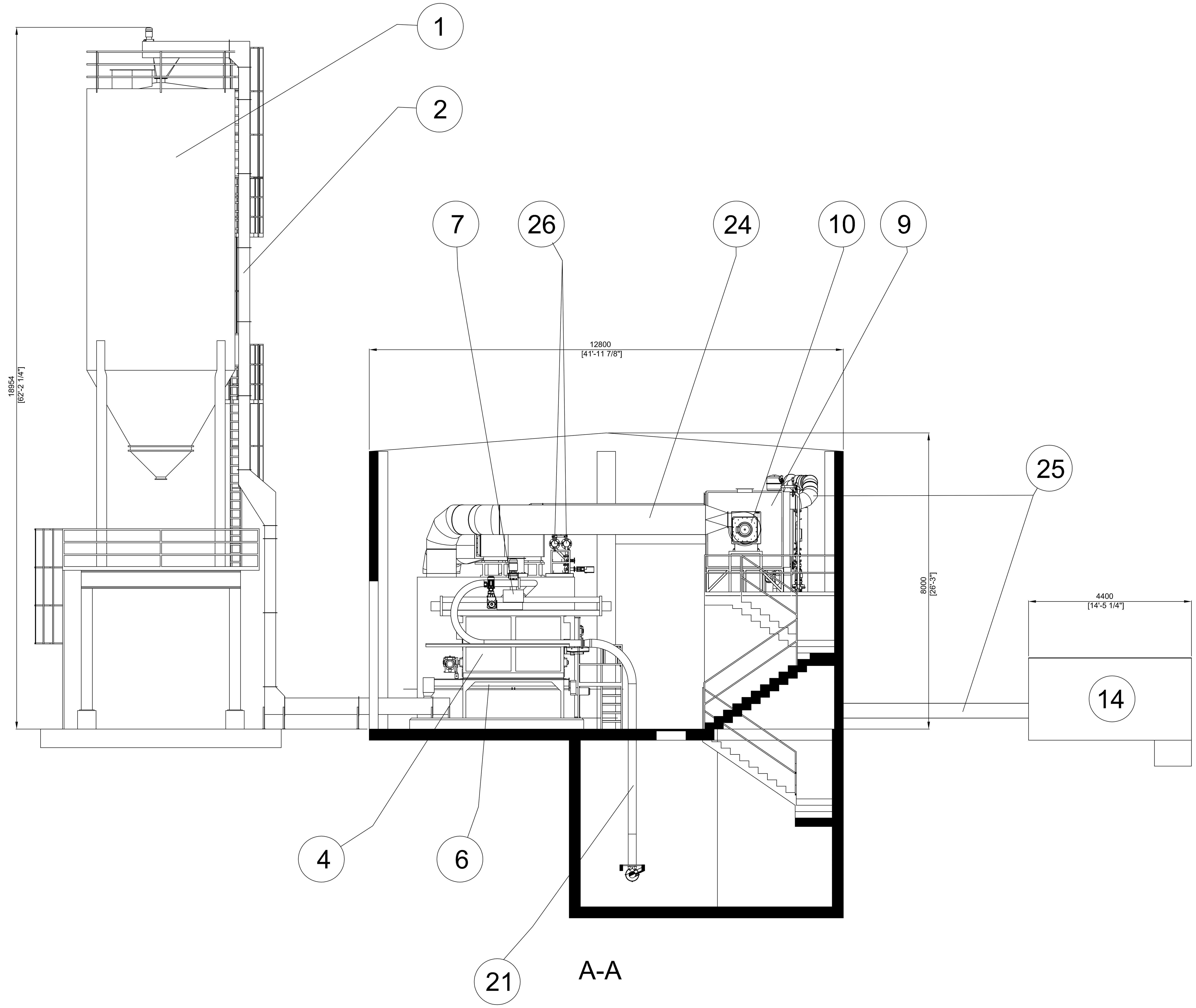
Massstab/Scale: 1:50

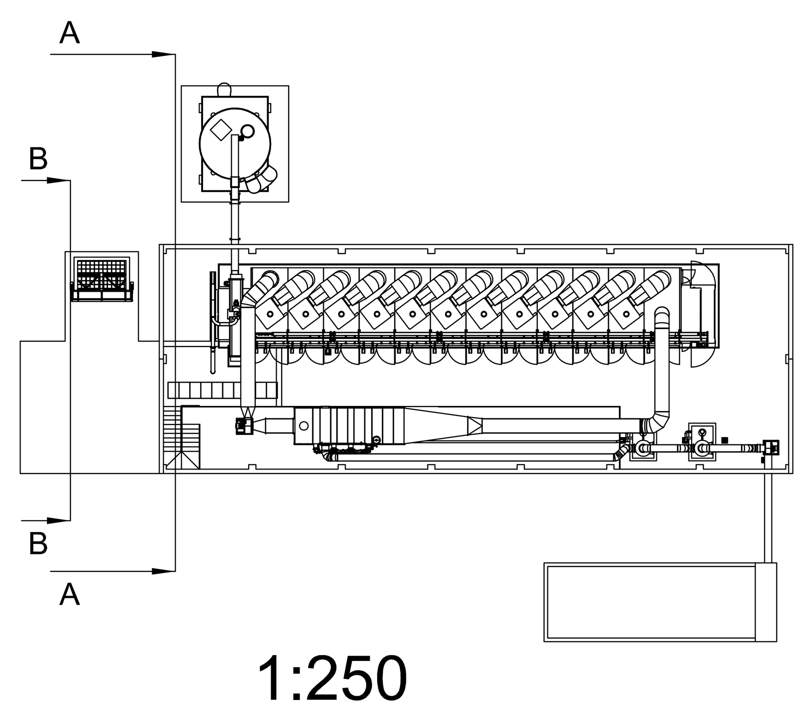
Trockner BT+ 24

dryer BT+ 24

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
	000001_290247	3/7





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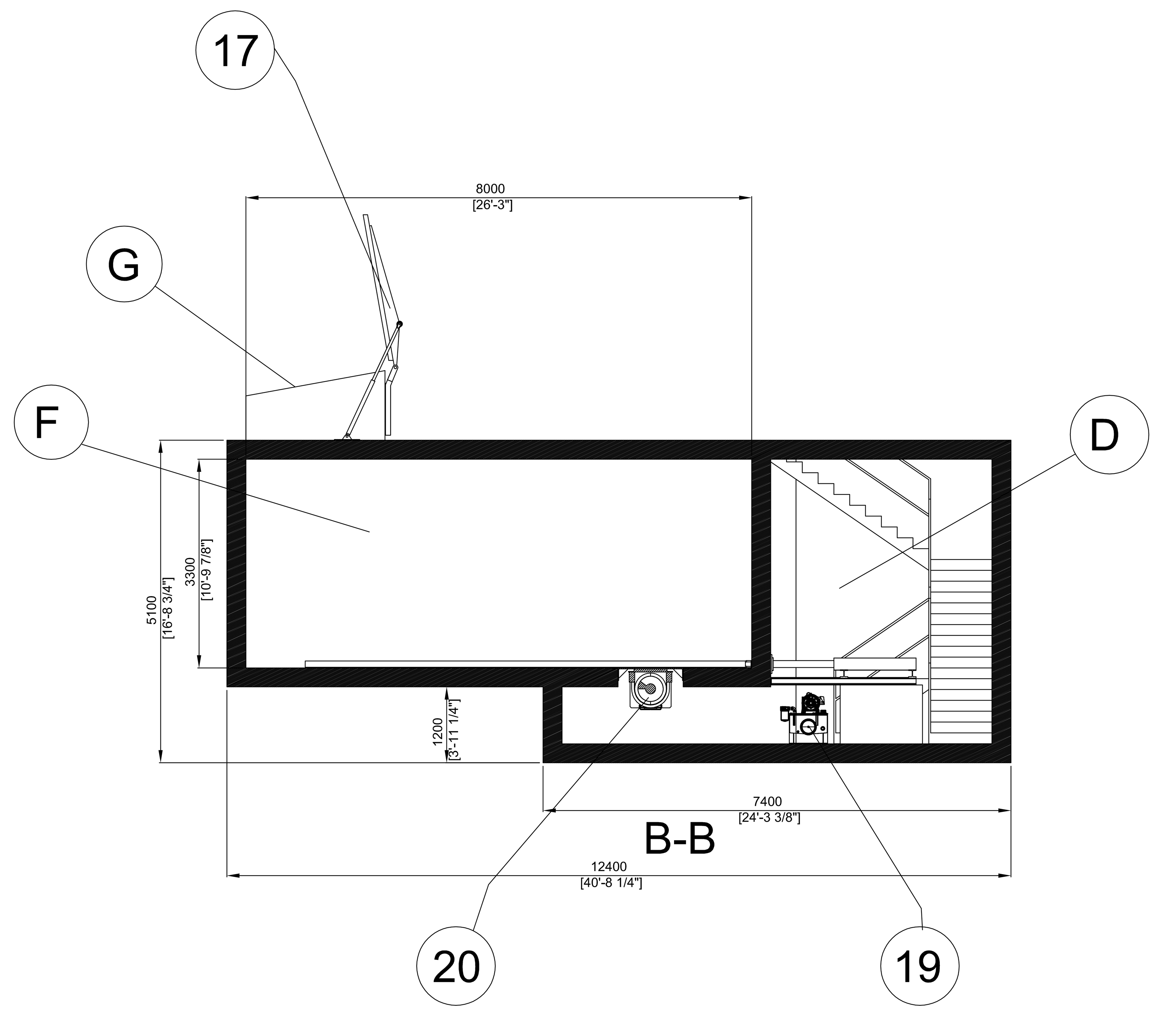

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
-	-	------------------------------ ----------------	-------------	

Technische Aenderungen vorbehalten / Subject to change

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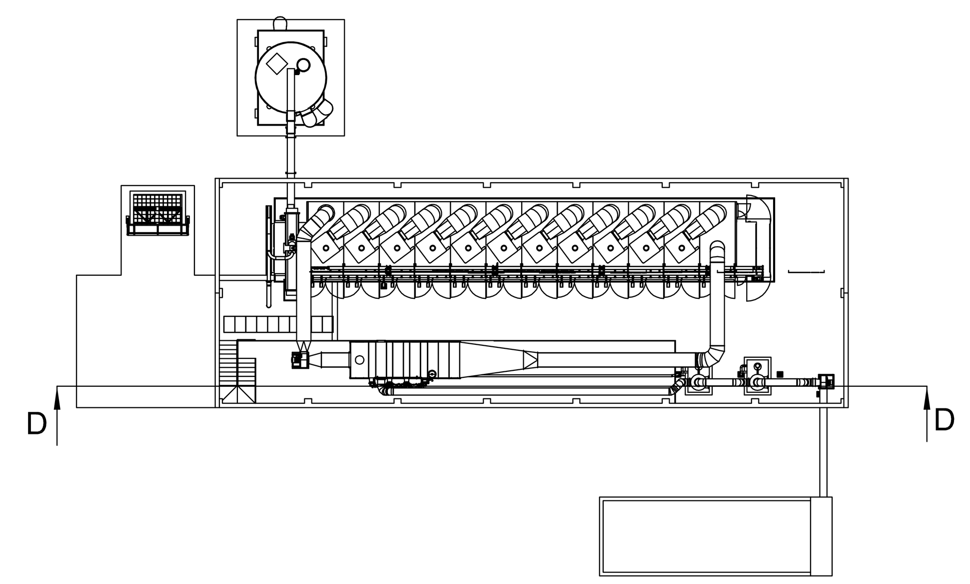
				Bear./Rev.	10.10.2013	kep
-	-	-	-	Gepr./Appr.	30.10.2013	hal
				Norm.		
				Massstab/Scale: 1:50		

Trockner BT+ 24

dryer BT+ 24

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
000001_290247		4/7



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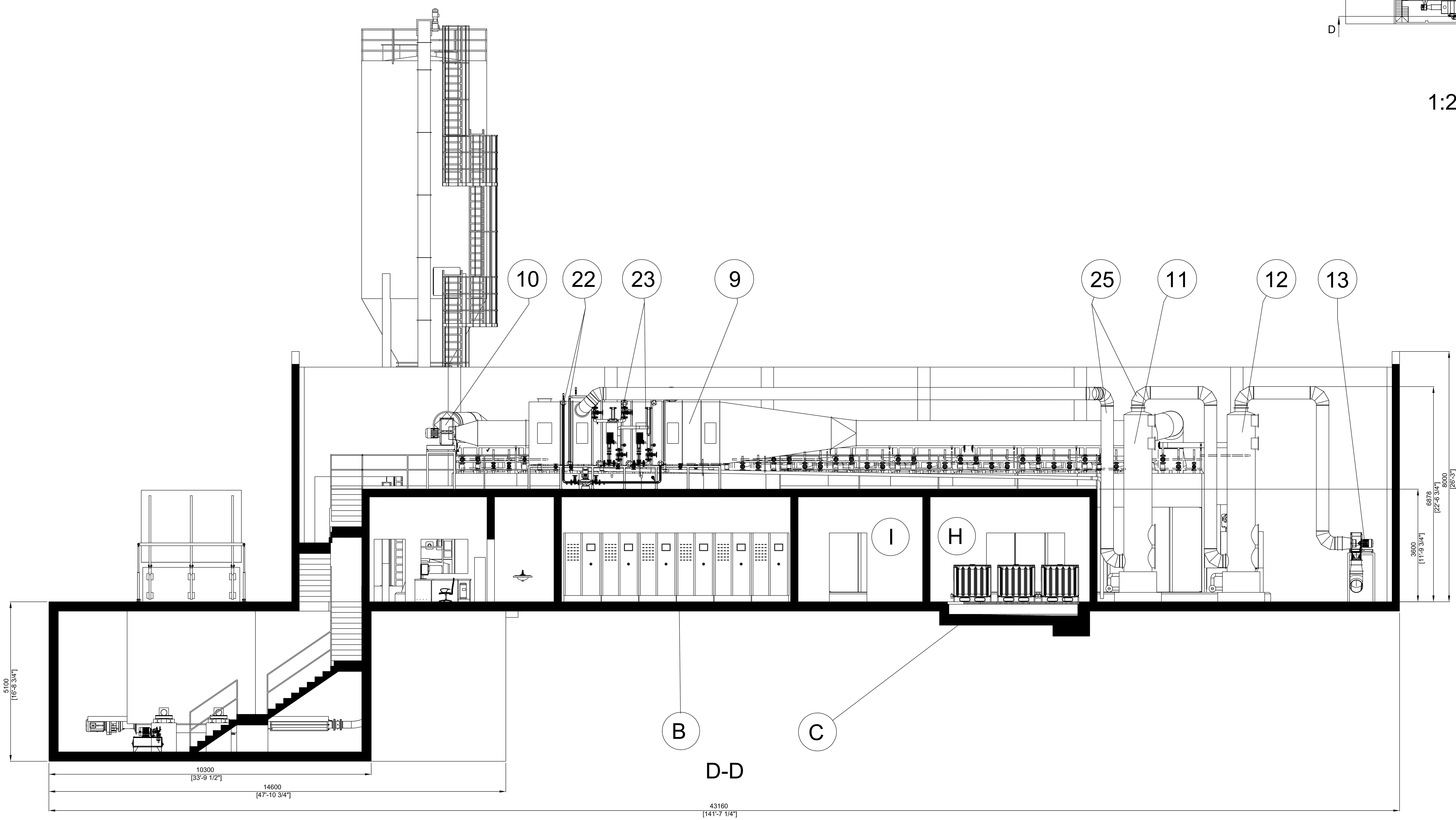

D-D

Pos. Item	Beschreibung	Description
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Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
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	Datum/Date	Name
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Gepr./Appr.	30.10.2013	hal
Norm.		

Revision	Aenderung Modified	Tag Date	Name
-	-	-	-

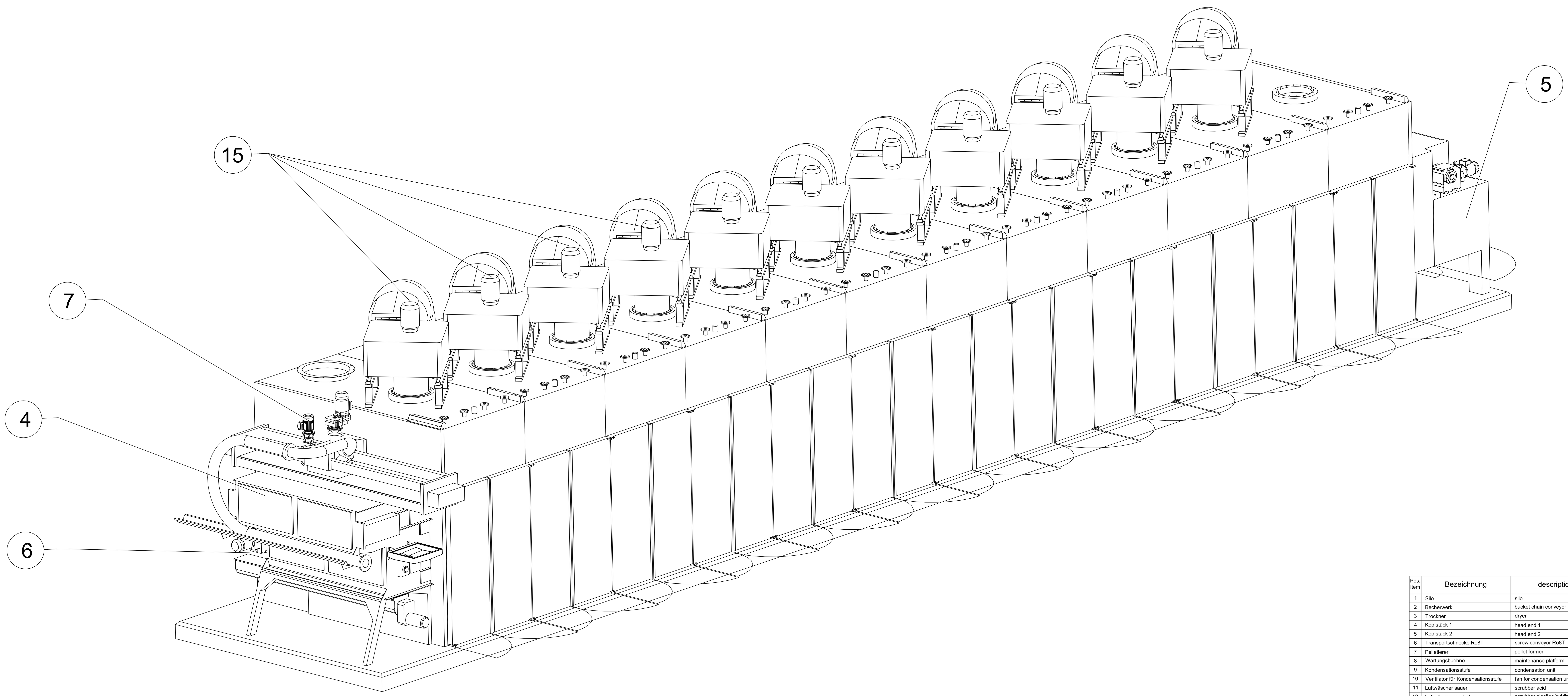
Massstab/Scale: 1:50

Trockner BT+ 24

dryer BT+ 24

Projektbez.: Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
	000001_290247	5/7



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7	Pelletierer	pellet former
8	Wartungsbuehne	maintenance platform
9	Kondensationsstufe	condensation unit
10	Ventilator für Kondensationsstufe	fan for condensation unit
11	Luftwäscher sauer	scrubber acid
12	Luftwäscher basisch	scrubber alcaline/oxidizing
13	Fortluftventilator	exhaust fan
14	Biofilter	biofilter
15	Prozessluftventilator	process air fan
16	Einfallschutz	fall protection
17	Bunkerdeckel	hydraulik bunker cover
18	Schubboden	live bottom wet sludge
19	Hydraulikaggregat	hydraulic power unit
20	Dickschlammpumpe	wet sludge pump
21	Dickschlammleitung	wet sludge pipe
22	Waermerueckgewinnung	heat recovery system
23	Kühlwasserverrohrung	piping for cooling water
24	Lüftungsrohr Umluft	air pipe condensation air
25	Lüftungsrohr Fortluft	air pipe exhaust air
26	Heizungsverteiler	heating distribution

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
-	-			

Technische Aenderungen vorbehalten / Subject to change — ISO 2768-mK

HUBER TECHNOLOGY
D-92334 Berching / Tel.: +49-8462-201-0

	Datum/Date	Name
Bear./Rev.	10.10.2013	kep
Gepr./Appr.	30.10.2013	hal
Norm.		

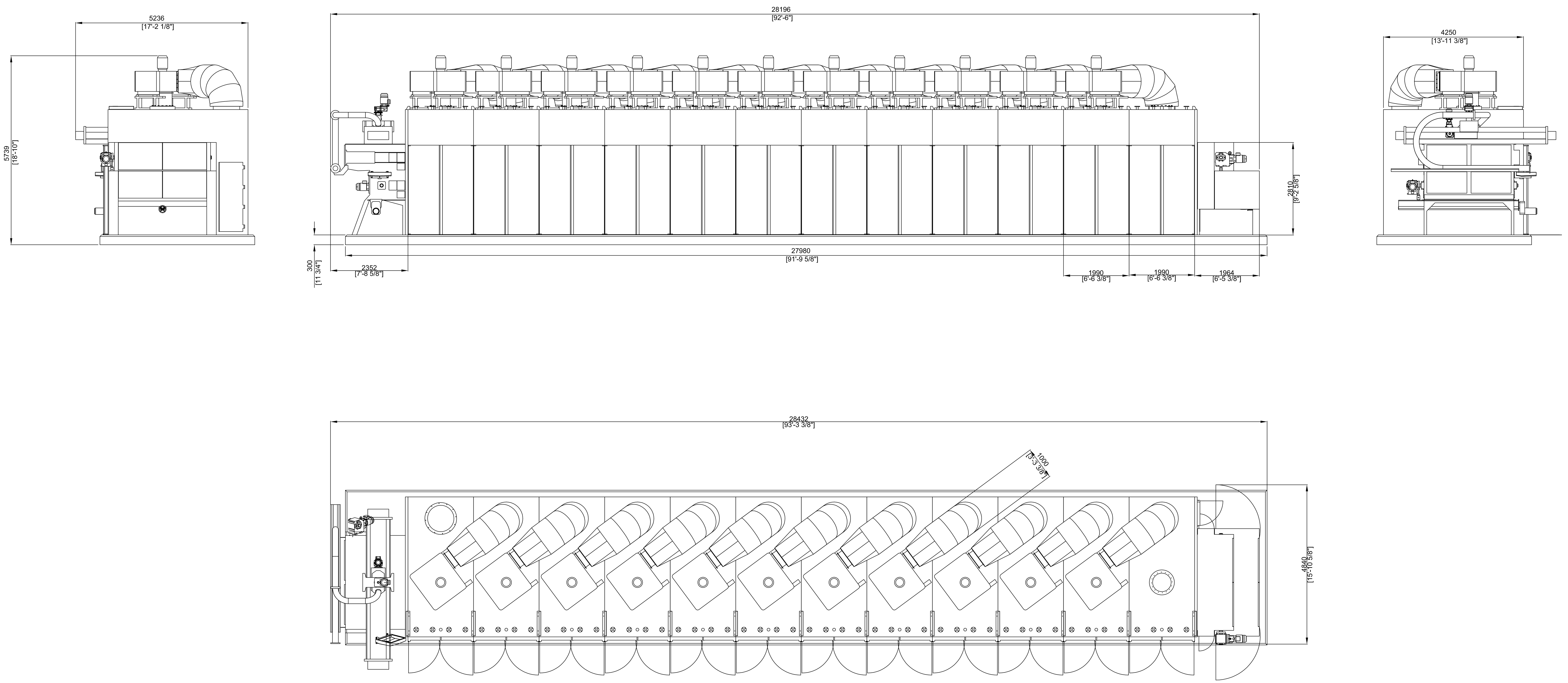
Revision: - | Aenderung Modified: - | Tag Date: - | Name: -

Massstab/Scale: 1:25

Trockner BT+ 24
dryer BT+ 24

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt / Project — Art.-Code / Item Code: 000001_290247 — Blatt / Sheet: 6/7



Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
-	-	------------------------------- -----------------	-------------	

Technische Aenderungen vorbehalten / Subject to change | ISO 2768-mK

HUBER TECHNOLOGY
D-92334 Berching / Tel.: +49-8462-201-0

Revi-sion	Aenderung Modified	Tag Date	Name		Datum/Date	Name
-	-	-	-	Bear./Rev.	10.10.2013	kep
				Gepr./Appr.	30.10.2013	hal
				Norm.		
				Massstab/Scale: 1:50		

Trockner BT+ 24
dryer BT+ 24

Projektbez.: / Project Name: Vertriebsunterstützendes Maßblatt

Projekt Project	Art.-Code Item Code	Blatt Sheet
	000001_290247	7/7

Komline-Sanderson Paddle Dryer Proposal

City Only Digesters Scenario (1,600 dry tons per year)

RBPF (5,800 dry tons per year)

Komline-Sanderson
12 Holland Av Peapack, NJ 07977-0257
908-234-1000 Fax: 908-234-9487
www.komline.com

June 26, 2019

Mr. John Ross

Ref: Paddle Dryer System
Anaerobically Digested Sludge Cake
Undisclosed Location
TPG-8149
Level 1 Budgetary Proposal

Thank you for your interest in the Komline-Sanderson Paddle Dryer. Based on the information provided, Komline-Sanderson would propose the following drying systems:

Process Conditions

Feed material: Anaerobically Digested Municipal Sludge Cake

	Case 1	**Case 2**
Feed solids:	24% DS	24%DS
Feed temperature:	70 °F	70 °F
System Design Rate:	21 WTPD	77 WTPD
	1,750 lb/h wet	6,417, lb/h wet
Evaporation rate:	1,293 lb/h	4,743 lb/h
Product:	92 % dry solids	92 % dry solids
Heating medium:	Thermal fluid	Thermal fluid
	400 gpm at 380 °F	750 gpm at 380 °F
Estimated gas usage:	1,800 cfh of natural gas	6,500 cfh of natural gas
	LHV=1,000 BTU/cft	
	2,770 cfh biogas	10,000 cfh of biogas
	LHV=650 BTU/cft	
Dryer operation:	168 hours per week	168 hours per week

Service Conditions

Plant power:	3 Ph, 60Hz, 440 Volts
Control voltage:	24 VDC, 110 VAC

Based on the provided information and K-S experience drying other anaerobically digested municipal sludges, we have selected a K-S Paddle Dryer Model 8W-580 to handle the requirements of Case 1, and a K-S Paddle Dryer Model 12W-1500 to handle the requirements of Case 2.

Scope of Supply

The following components are to be provided by Komline-Sanderson per Case:

1. One (1) wet cake storage hopper will temporarily store the wet cake from the dewatering device.

   For the Model 8W-580, a 30 cyd wet cake storage hopper will consist of two spiral screws in a stainless-steel omega shaped trough. Each screw is powered by a 5 hp shaft mounted drive. A stainless-steel hopper mounted above the live bottom screws will provide the extra volumetric capacity specified.

   For the Model 12W-1500 the 90 cyd wet cake hopper will be a circular sliding frame silo as manufactured by Schwing, Bioset, Spirac, or equal. The silo and hydraulically driven sliding frames will be fabricated from carbon steel. Hydraulic power unit and controls are included.

2. One (1) progressive cavity feed pump as manufactured by Seepex, Moyno, or equal: Located directly below the wet cake hopper, a pump is provided to pump the sludge cake to the dyer. The pump is controlled by a variable frequency drive provided by others. The feed rate to the dryer is adjusted by changing the speed of the pump. Pump motor powers are specified below for each case:

   Case 1: 10 hp

   Case 2: 30 hp

3. One (1) K-S Paddle Dryer, as specified below for each case: All process wetted parts are manufactured from stainless steel to protect the dryer against corrosion. To protect against abrasion, hard surfacing is weld applied to 2/3 of the paddles as well as the entire trough. A TEFC motor, with powers specified below, is used to rotate the dual intermeshing shafts that mix, heat, and dry the product. As the material enters the final drying stages, the product temperature will start to rise. Komline-Sanderson's control system monitors the product temperature and can adjust a discharge weir at the back of the dryer to maintain a consistent product.

   Case 1: Model 8W-580, with 60 hp Motor

   Case 2: Model 12W-1500, with 125 hp Motor

   Dryer insulation, thermal fluid manifold piping, platform, deflagration panels and vent, and automatic weir for product control are included.

4. One (1) rotary valve between the K-S Paddle dryer and the product conveyors.

5. One (1) product handling system consisting of a dryer discharge conveyor, jacketed cooling conveyor, product transfer screw conveyor (which also may be jacketed), product loadout conveyor and product load out spout. Materials of construction is stainless steel for all conveyors.

6. One (1) Off-gas system: The system will condense the evaporated water in a spray tower condenser. The condenser is fabricated from stainless steel and will cool and condense the dryer off-gas. The condenser effluent will need to be treated for odor. An exhaust fan is included to vent the non-condensable constituents to an odor control system currently not defined. Refer to the discussion below concerning odor control systems.
7. One (1) thermal fluid heating system, as specified below for each case: The system includes a heater with natural gas or digester gas fuel train and pilot train, burner controls with 7:1 turn down to modulate the heater firing rate to maintain a consistent thermal fluid temperature, combustion fan, thermal fluid recirculating pump, thermal fluid expansion tank, and control panel. All components are pre-wired and skid-mounted with the exception of the expansion tank which must be bolted to the top of the skid in the field. A thermal fluid cooler heat exchanger is also provided for shut down operation. Thermal fluid to fill the system is included.

   Case 1: 2.5 MMBTU/h

   Case 2: 6.6 MMBTU/h
8. Instrumentation and Controls: The system is controlled by an Allen Bradley panel-mounted PLC with Operator Interface Terminal. The control panel will be a free standing NEMA 4X panel located near the dryer. MCC and VFD's are supplied by others. An industrial desk top PC computer with keyboard, mouse, and monitor are included to provide as a separate desktop HMI station that is more operator friendly. From the PC station, operators will also be able to access long term operational trends, Equipment Manuals and other reference sources.
9. System integration: K-S will provide Process Flow Diagrams, Piping and Instrumentation Diagrams, General Equipment Layout Drawings, OEM Manuals for all equipment and instruments provided, as well as 40 days of start-up service and operator training. Additional start-up service can be offered as optional.

Odor Control:

When drying municipal sludges, there are numerous volatile constituents present in minute quantities which lead to the issue of odors. These constituents can be broken down into three subcategories:

a) Volatile Organic Compounds (VOC) and formaldehydes such as benzene, toluene, acetone, acetaldehyde, isobutyraldehyde, etc.
b) Volatile Sulfur Components (VSC), such as hydrogen sulfide, methyl mercaptan, carbon disulfide, dimethyl sulfide, carbonyl sulfide, etc.
c) Amines such as ammonia, methyl pyrazine, etc.

Komline Sanderson has tested numerous municipal sludges in our pilot facility and on several occasions, an independent lab was brought on site to take air samples and test for odor constituents and concentrations. Although there are some compounds that are common in some sludge dryers (but not all), their concentration levels greatly differ depending on the source of the sludge and how the sludge was treated. Therefore, to determine the actual composition and concentration of these odorous constituents, the off gas must be tested.

The amount of non-condensable gases exiting from our drying system is small, about 300 cfm. Therefore, if a plant odor control system already exists, K-S recommends that this small amount of dryer gas be sent there. Very often these plant odor control systems are designed for 1,000's of cfm and an additional 300 cfm of gas is an insignificant addition.

If a plant odor control system does not exist, but there is an aeration basin in the plant, then K-S recommends the off-gas be sent to the aeration basin where it can percolate through the basin. Komline-Sanderson can supply a liquid ring compressor and a small coarse bubble diffuser. The diffuser is located about eight feet below the surface. This option has the advantage in that there is no "exhaust stack" which requires permitting.

If an aeration basin is not available, then the question defaults to odor control using either a biofilter or chemical scrubber. A polishing carbon filter will also be needed as there are some odor constituents that are not treated by either a biofilter or chemical scrubber.

The choice between the biofilter and chemical scrubber should be made based on the operation of the dryer, plant preference, and the results of an off-gas test that has properly qualified and quantified the odor constituents. Both biofilters and chemical scrubbers have their pros and cons and the decision to go either way should be based on information that is currently not available.

Finally, a thermal oxidizer provides another means of odor destruction. However, this option is very rarely used due to the low flow and high capital cost.

Exclusions:

The following equipment, material, and services are excluded from the Komline-Sanderson scope of supply.

- ❖ Wet cake transfers to our hoppers
- ❖ Dry product handling after our cooling conveyors
- ❖ Additional odor control equipment after our exhaust fan
- ❖ Saturated Steam supply
- ❖ Plant water supply and return for cooling conveyor and condenser/scrubber
- ❖ Compressed Air for dryer shaft seals
- ❖ Building

- Any and all permits
- Insurance certificates
- Taxes of any kind
- Receipt and off loading of all equipment supplied
- Installation of equipment and re-assembly when required
- Supply and installation of interconnecting piping, fittings and all valves
- Gaskets and fasteners for the points of interface with ducts and piping supplied by others
- Piping isometric and installation drawings. Piping and Instrumentation line drawings are supplied.
- Supply and installation of external insulation. K-S will insulate the dryer. Client will install the K-S supplied dryer cover blanket.
- Design and supply of concrete supports
- Design, fabrication, and installation of equipment support steel not referenced
- Design, supply, and installation of interconnecting wire, cable, conduit tubing, etc.
- Operational consumables such as oil, grease, chemicals/reagents
- Field painting, including touch up paint
- Surety bond, if required
- Certified equipment tests
- Motor control center (MCC), motor starters and variable frequency drives (VFDs)
- Local disconnects and HOA stations if required
- Spare parts
- Any other equipment, material, or service not specifically identified within this quotation

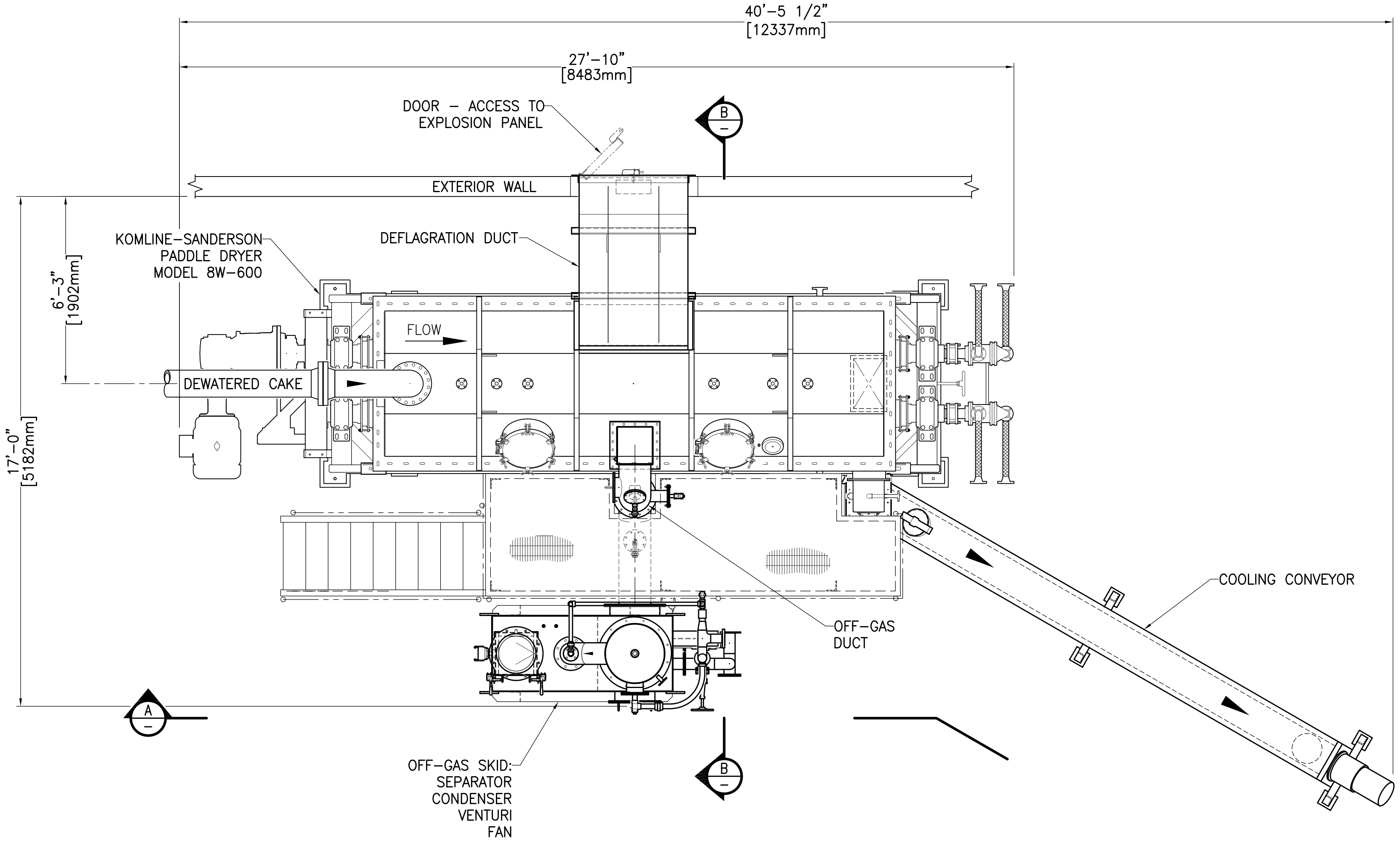
The budget estimates for the K-S Paddle Dryer systems with associated equipment and services for the two proposed cases are presented below:

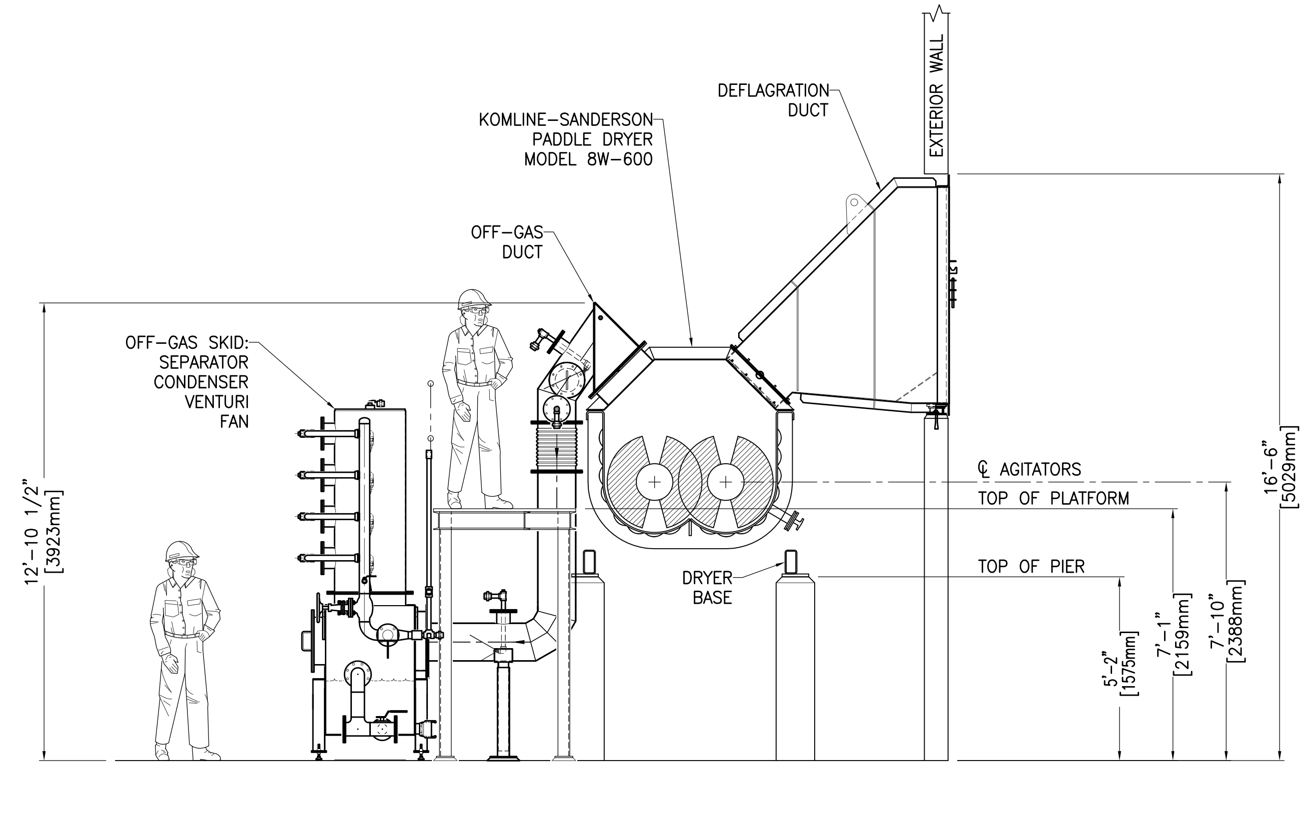
Case 1:	One (1) 8W-580 Biosolids Drying System	$ 2,350,000 USD
Case 2:	One (1) 12W-1500 Biosolids Drying System	$ 4,100,000 USD

If the above drying system(s) are of interest, we should have some discussions with the plant manager and engineer to discuss various design details to solidify a system design that integrates well with the current operations of the plant.

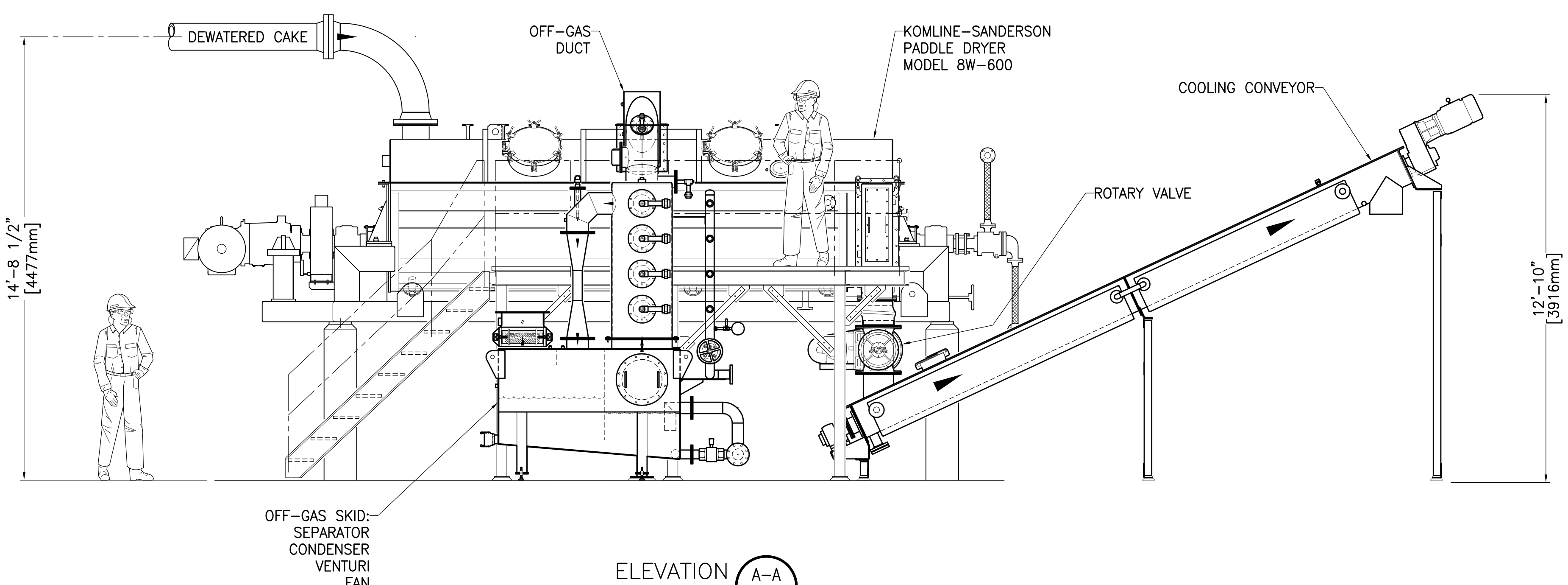
Yours truly,

Les Lattig
Municipal Sales Engineer
(908) 234-1000 X335
ljlattig@komline.com





ELEVATION B–B



ELEVATION A–A

NOTES:

1. NOT FOR CONSTRUCTION. THE INFORMATION IN THIS DRAWING IS INTENDED TO RELAY CONCEPTUAL INFORMATION AND IS TO BE USED FOR GENERAL DISCUSSION AND PLANNING. THIS DRAWING IS PRELIMINARY AND IS SUBJECT TO CHANGE WITHOUT NOTIFICATION AS NEW INFORMATION IS MADE AVAILABLE DURING THE DESIGN STAGE.
2. SOME SYSTEM COMPONENTS ARE NOT SHOWN ON THIS DRAWING (e.g. THERMAL FLUID HEATER OR STEAM BOILER, DRY PRODUCT TRANSPORT).
3. PIPING NOT SHOWN.
4. VENTURI AND FAN MAY BE REPLACED WITH AN ALTERNATE LIQUID RING COMPRESSOR.

CONFIDENTIAL

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KOMLINE-SANDERSON ENGINEERING CORPORATION

REV	DRWN	CHKD	DATE	APPR

TITLE: BIOSOLIDS DRYING SYSTEM
K-S PADDLE DRYER
MODEL 8W-600

CONCEPT
SYSTEM ARRANGEMENT

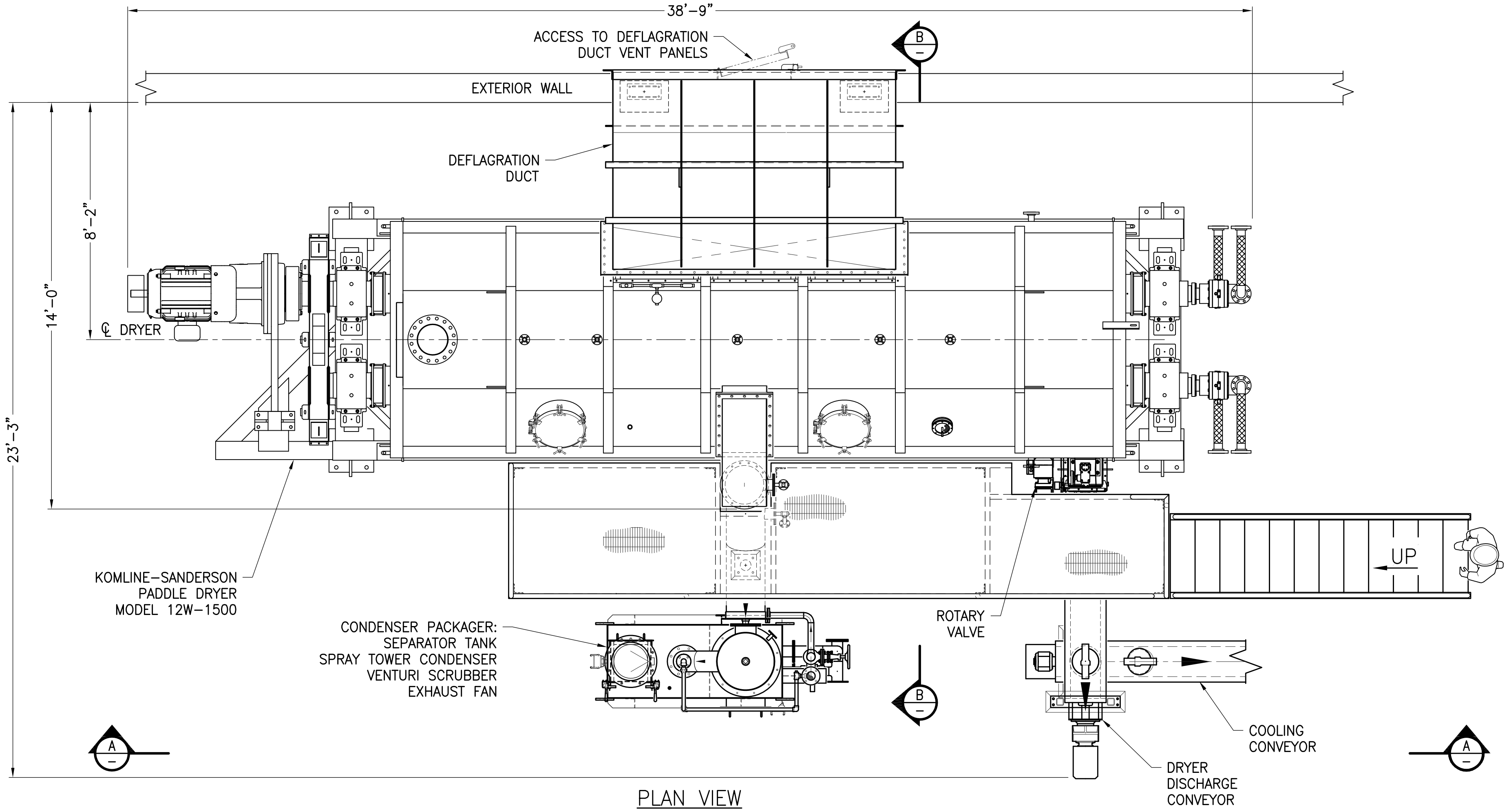
DATE	SCALE	DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY
2014-05-28	1=32	TGP	TGP	-	-

KOMLINE–SANDERSON
ENGINEERING CORPORATION
PEAPACK, NJ 07977 USA

REFERENCE:
SHT 1 OF 1
DRAWING NO. 8W600S-S-CVF-RC-20151016
REV

PRINT MAY BE REDUCED SIZE, DO NOT SCALE. =ONE INCH(1")

01-JUL-02 J:\053-Dryers-Coolers\Sales Dwgs (Current)\Dryer Systems\8W600S-S-CVF-RC-20151016.dwg, 10/16/2015 9:03:18 AM, TGPerret



PLAN VIEW

NOTES:

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2. SOME SYSTEM COMPONENTS ARE NOT SHOWN ON THIS DRAWING (e.g. THERMAL FLUID HEATER, FEED HOPPER, ETC).
3. PIPING NOT SHOWN.
4. VENTURI AND FAN MAY BE REPLACED WITH AN ALTERNATE LIQUID RING COMPRESSOR.

CONFIDENTIAL PRELIMINARY

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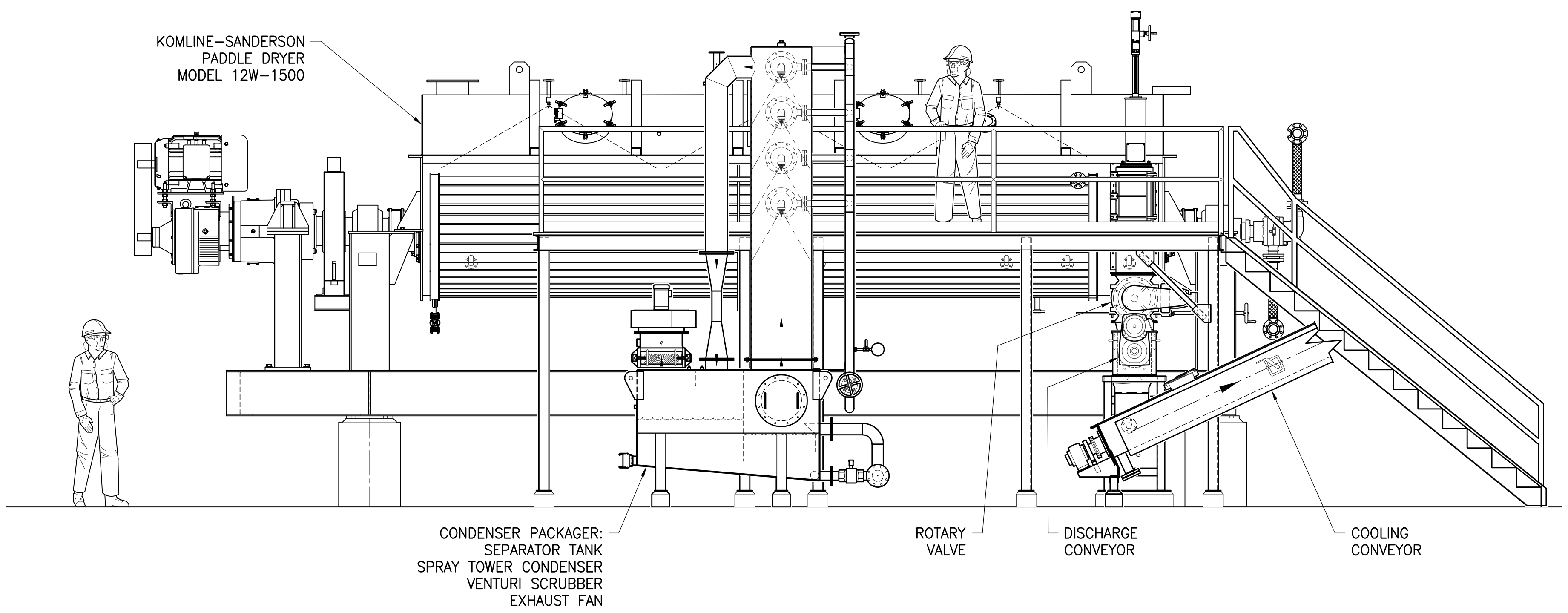
NOT FOR CONSTRUCTION. The information in this drawing is intended to relay conceptual information and is to be used for general discussion and planning. This drawing is preliminary and is subject to change without notification as new information is made available during the design stage.



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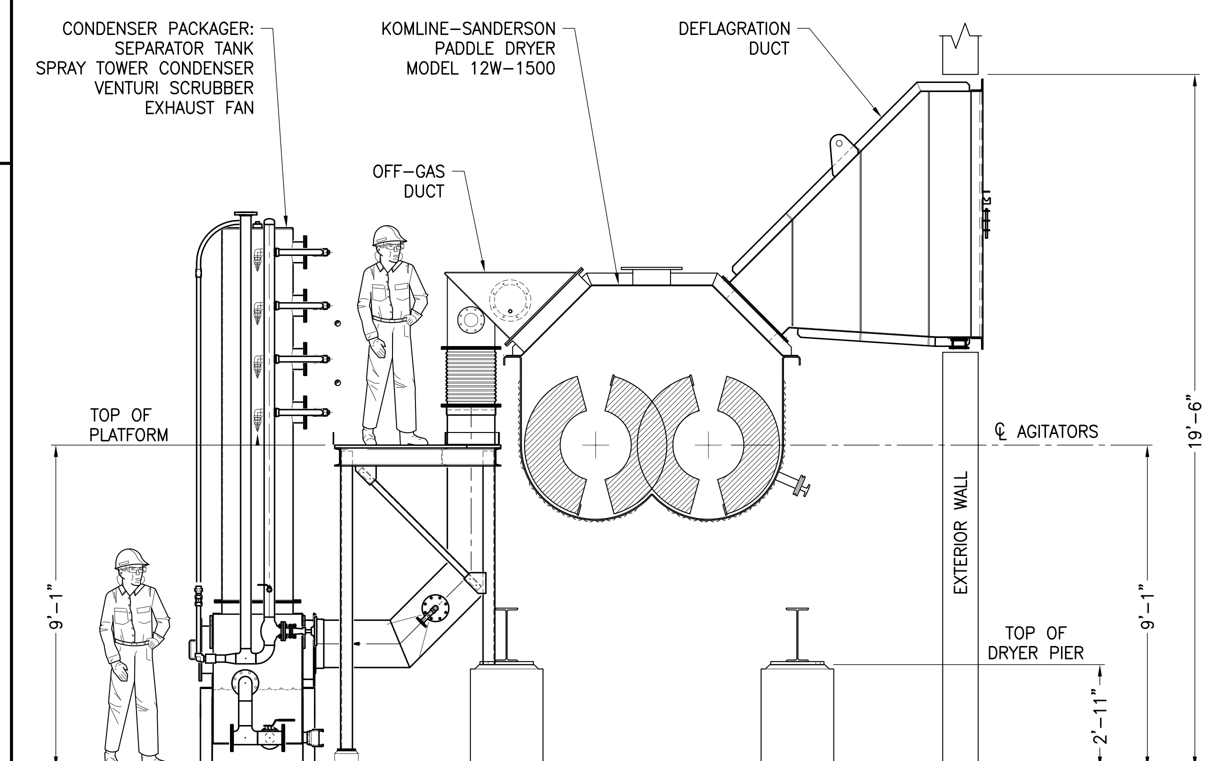

ELEVATION B-B

REV	DRWN	CHKD	DATE	APPR

TITLE: BIOSOLIDS DRYING SYSTEM
K-S PADDLE DRYER
MODEL 12W-1500

CONCEPT SYSTEM ARRANGEMENT

DATE	SCALE	DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY
2018-12-18	1=32	TGP	TGP	-	-

KOMLINE-SANDERSON CORPORATION
PEAPACK, NJ 07977 USA

REFERENCE: -
SHT 1 OF 1
DRAWING NO. 12W1500S-S-CVF-RDC-20181218
REV -

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PRINT MAY BE REDUCED SIZE, DO NOT SCALE. = ONE INCH(1")

Andritz Drum Dryer Proposal

RBPF (5,800 dry tons per year)

Integrated dewatering and drying, Nashville, Tennessee

Regional Drying Plant Manatee County, Bradenton, FL

ANDRITZ designs and builds dewatering and drying facilities around the world, with 35 facilities in North America. ANDRITZ can provide equipment supply only or complete design or build services as required.

For more information:

Andritz Separation Inc.
1010 Commercial Blvd., South
Arlington, Texas 76001 USA
+1 (817) 465-5611

Peter Commerford
Manager, Drying System
peter.commerford@andritz.com
+1 (817) 419-1719 (office)
+1 (817) 271-2855 (cell)

Integrated dewatering and drying, Ocean County, NJ

Integrated dewatering and drying facility, Sacramento, CA

DDS 40 located Waco, TX – In service since 1994

ANDRITZ Drum Drying System DDS

North American Bio-solids Facility Tour

DDS 40 located Pinellas County, FL – In service since 2004 (operated by Synagro)

DDS 20 located Pierce County, WA – In service since 2004

- *Produces desirable, quality beneficial use product for the agricultural /fertilizer market segments*
- *Proven in over 25 years of operating experience*
- *Meets 503 reg. for pathogen reduction and vector attraction*
- *Gas recirculation for safe operation and the most cost effective emission control*
- *Technology enhancements focusing on energy consumption reduction/ alternative fuels*
- *Highly experienced delivery team*

ANDRITZ
ENGINEERED SUCCESS

Drum Drying System DDS


DDS 40 in Aiken, SC - In service since 1997


DDS 60 in Winston-Salem, NC - In service since 2005


DDS 40 in Encina, CA - In service since 2005


2 x DDS 120 in Philadelphia, PA - In service since 2012


DDS 20 in Bonita Springs, FL - In service since 2005


DDS 40 in Cary, NC - In service since 2004


4 x DDS 100S in Louisville, KY - In service since 2002


2 x DDS 80 in Houston, TX - In service since 2008


DDS 50 in Tallahassee, FL - In service since 2012


DDS 40 in Honolulu, HI - In service since 2004

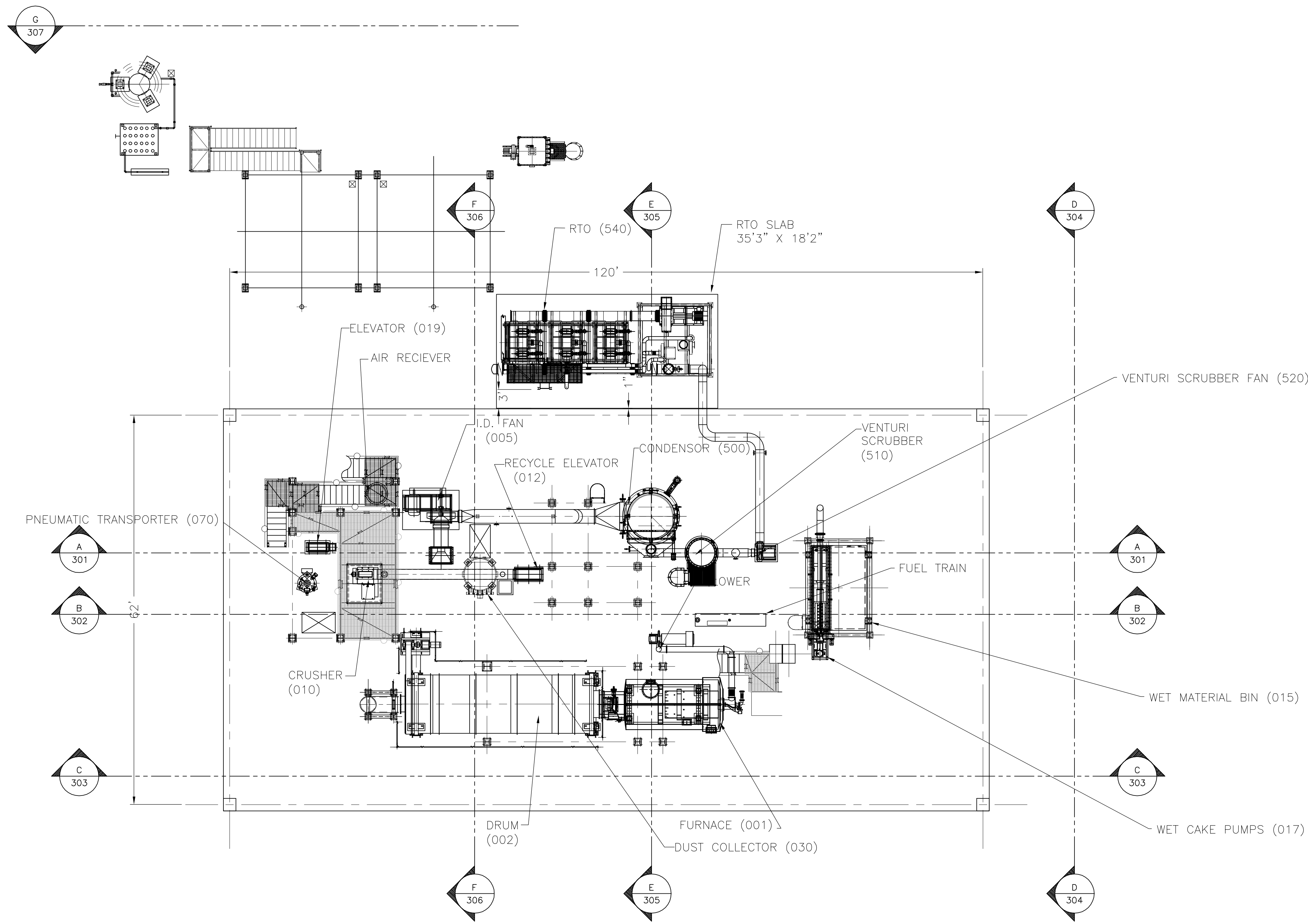

DDS 40 in Stamford, CT - In service since 2008


DDS 20 in Leesburg, VA - In service since 2000

City of Portsmouth, NH
Dryer Economic Evaluation
1st year Ownership Cost Estimate

Scheme	Regional
Dewatering Device	BFP
Plant Rate	63 wet TPD
Wet feed cake solids	25% DS
Operations Basis	4.0 days/ week
Operations Basis	24 hours/day
Operations Basis	4,992 hours/year
Dryer Cake feed	110 wet TPD
Dryer Dry Feed	27.5 dry TPD
Final moisture content	92% DS
Final Product	29.9 TPD
Evaporation Rate	6,670 lbs/hr H2O
Evaporation Rate	3,025 kg/hr H2O
No, of Drying Lines	1
Dryer model selected	BDS-40
Annual Biosolids Processed	5,715 dry tons/year
Summary of Costs	
Capital Cost-Equipment only	$7,000,000
Odor Control measures	$1,000,000
Cake Intake System	$1,500,000
Facility Cost Factor 2.5	$23,750,000
Heat Energy	$575,236
Electrical Energy	$175,762
Labor Cost	$280,800
Maintenance Cost	$190,000
Pellet Revenue	$0
Annual Cost of Ownership	**$1,221,798**
Cost per dry Ton of sludge	$213.80
Cost per wet Ton of sludge	$53.45
T&D Cost per wet ton	$70.00
Heat Energy	**1,300 BTU/ lb.**
Heat requirement/ hour	8.67 MM BTU/hr
Heat requirement/ year	43,283 MM BTU/yr
Natural gas purchased	43,283 MM BTU/yr
Gas Cost/ unit	**$13.29 /MM BTU**
Annual Gas Cost	$575,236
Electrical Energy	**$0.139 /kW-hour**
Connected power	400 HP
Ulitilisation Factor	0.85
Absorbed power	253 kW
Annual Electrical Cost	$175,762
Labor Cost (incl. fringe benefits)	**$45.00/ hour**
No. of shifts	3
Operations personnel/ shift	1
Annual Labor cost	$280,800
Maintenance Cost	**2% equipment cost**
Base dryer capital cost	$9,500,000
Annual Maintenance Cost	$190,000
Pellet Revenue	$0.00 / ton pellets
Annual Pellet Revenue	$0

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: DAN	DATE: 5/12/10
CHECKED BY:	DATE:
APPROVED BY:	DATE:
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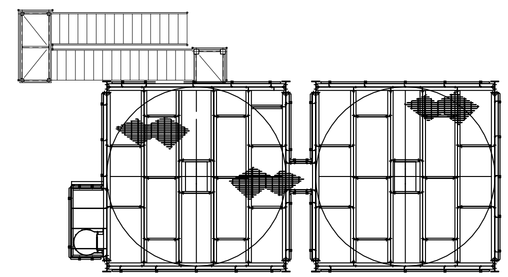
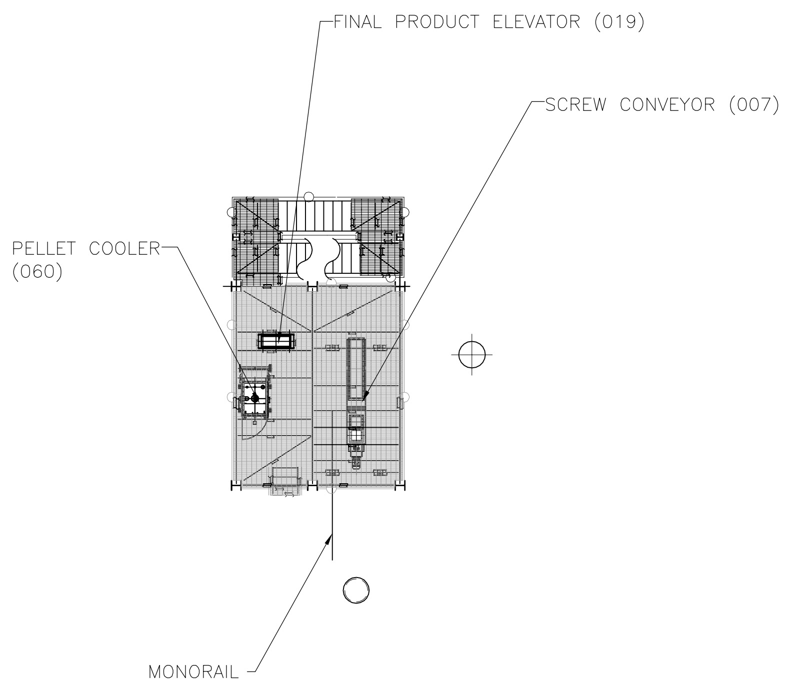
SIZE	DDS40
JOB NAME	ROTARY DRYER SYSTEM
TITLE	DRYER AREA PLAN VIEW AT EL. 200'-0"
PROJECT NUMBER	
DRAWING NUMBER	ME-101
REV	A
SHEET	1 OF 1

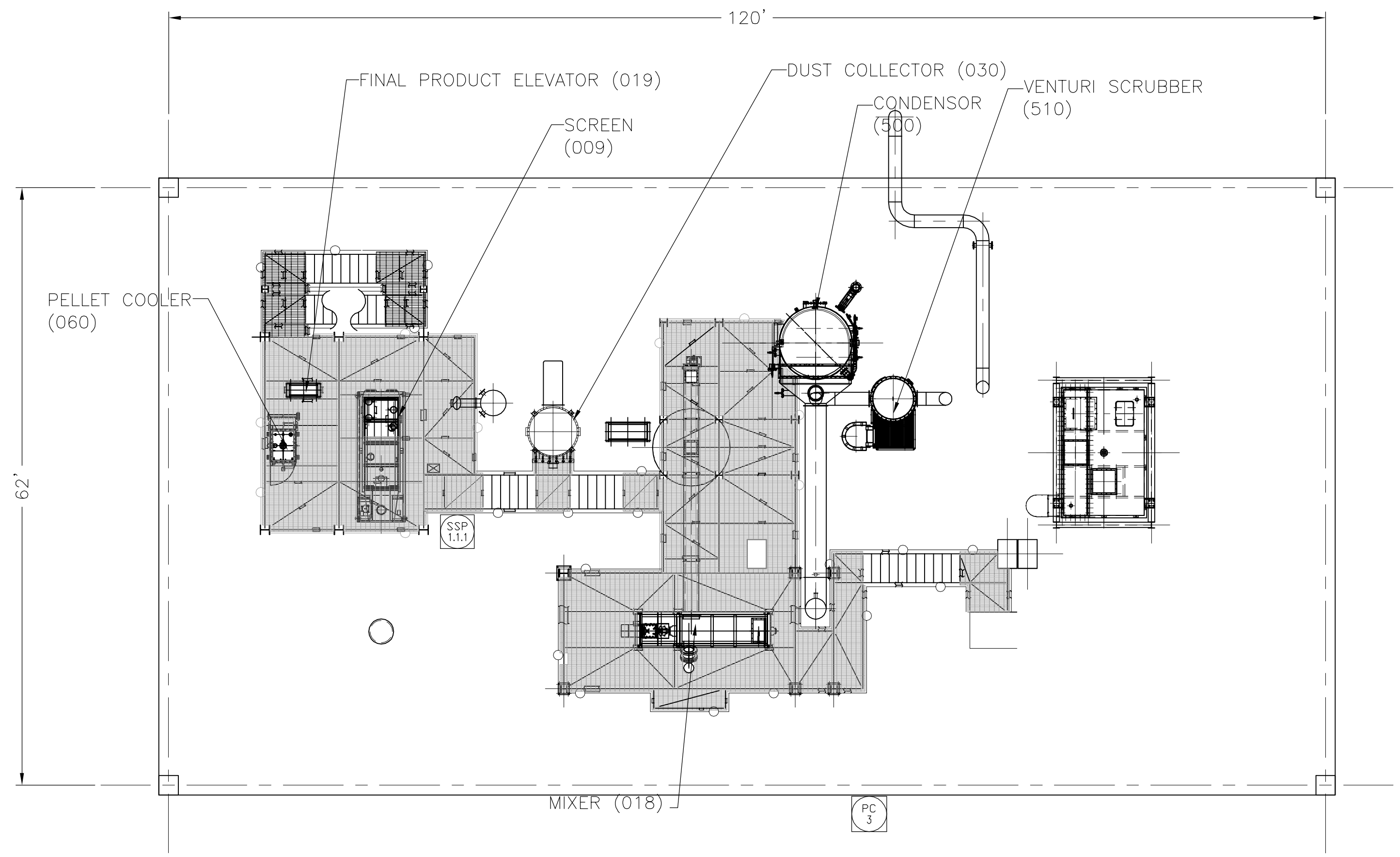
PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.





PLAN @ T.O.S. EL. 225'-0 1/2"



PLAN @ T.O.S. EL. 214'-6 1/2"

PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

ANDRITZ
ANDRITZ SEPARATION, INC.
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ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: DAN	DATE: 5/12/10
CHECKED BY:	DATE:
APPROVED BY:	DATE:
SCALE: 1"=10'	FILE: ME102
SIZE:	DDS40

JOB NAME: ROTARY DRYER SYSTEM

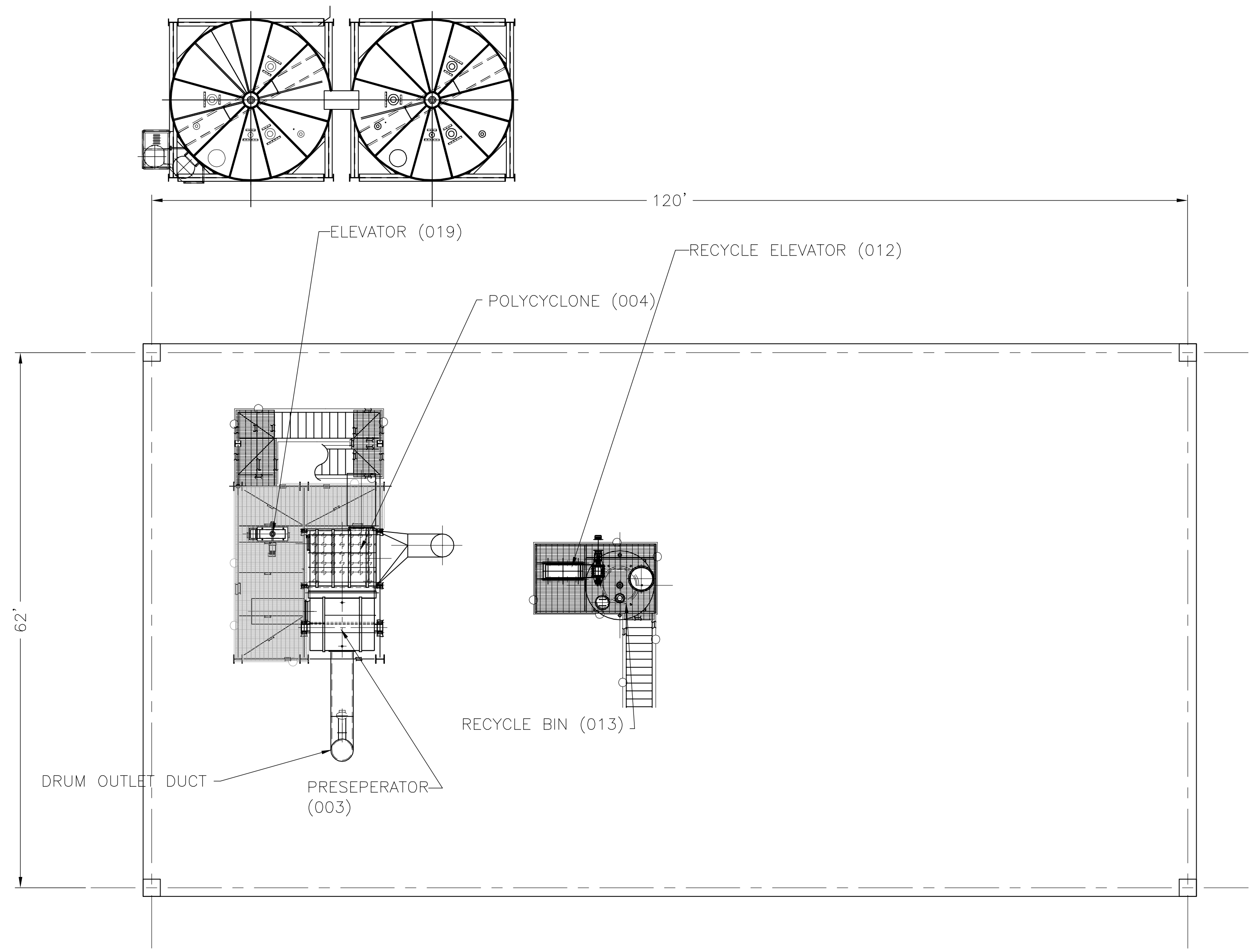
TITLE: DRYER AREA PLAN VIEW AT EL. 214'-6 1/2"

PROJECT NUMBER

DRAWING NUMBER: ME-102 REV: A

SHEET 1 OF 1

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



PLAN @ T.O.S. EL. 237'-6 1/2""

PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

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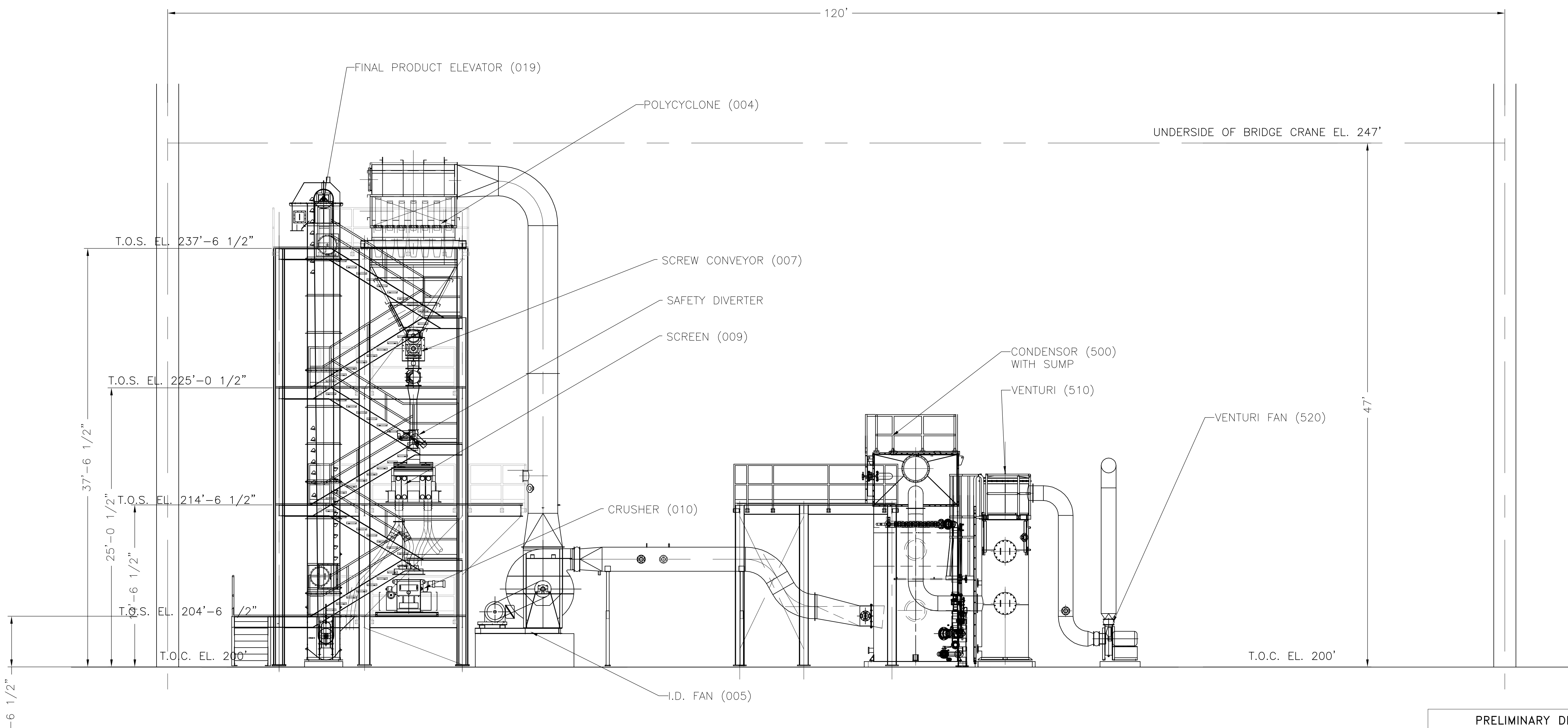
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: DAN DATE: 5/12/10
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: 1"=10' FILE ME103
SIZE DDS40

JOB NAME: ROTARY DRYER SYSTEM
TITLE: DRYER AREA PLAN VIEW AT EL. 237'-6 1/2"
PROJECT NUMBER
DRAWING NUMBER ME-103 REV A
SHEET 1 OF 1

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



A SECTION A-A

PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

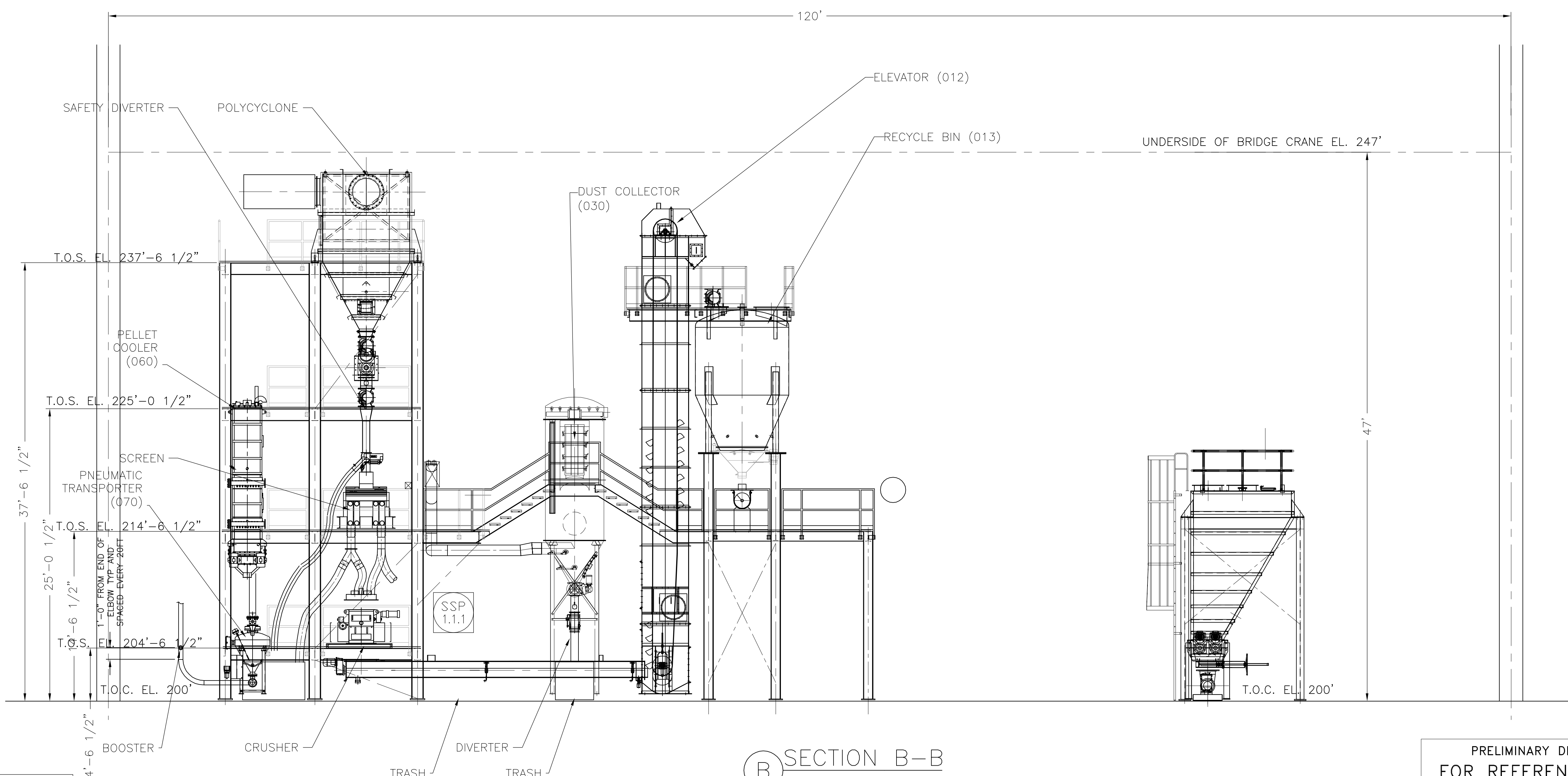
ANDRITZ
ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

REV	REVISION	DATE

DRAWN BY: DAN — DATE: 5/12/10
CHECKED BY: — DATE:
APPROVED BY: — DATE:
SCALE: 3/16"=1'-0" — FILE: ME301
SIZE: DDS40

JOB NAME: ROTARY DRYER SYSTEM
TITLE: DRYER AREA SECTION A-A
PROJECT NUMBER
DRAWING NUMBER: ME-301 — REV: A
SHEET 1 OF 1

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



B SECTION B-B

PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

ANDRITZ
ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

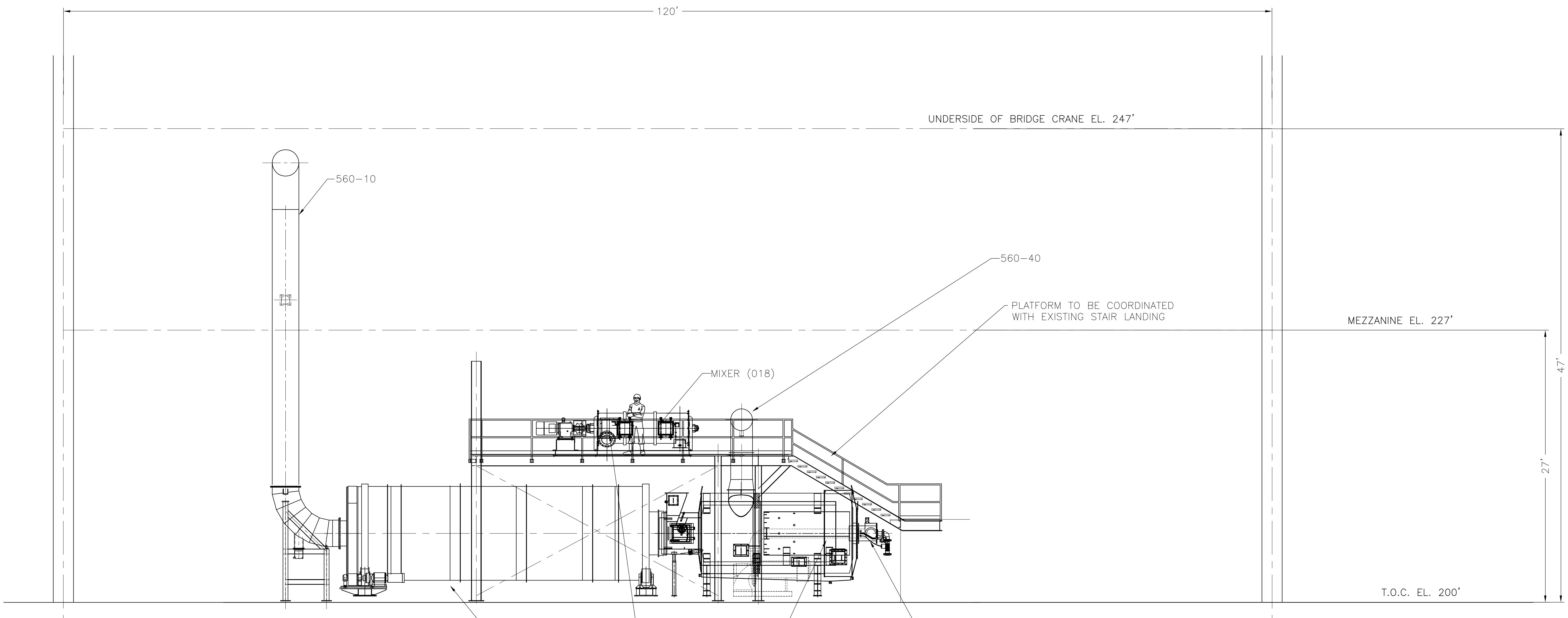
DRAWN BY: DAN | DATE: 5/12/10
CHECKED BY: | DATE:
APPROVED BY: | DATE:
SCALE: 3/16"=1'-0" | FILE: ME302
SIZE

DDS40

REV | REVISION | DATE

JOB NAME: ROTARY DRYER SYSTEM
TITLE: DRYER AREA SECTION B-B
PROJECT NUMBER
DRAWING NUMBER: ME-302 | REV: A
SHEET 1 OF 1

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



SECTION C-C

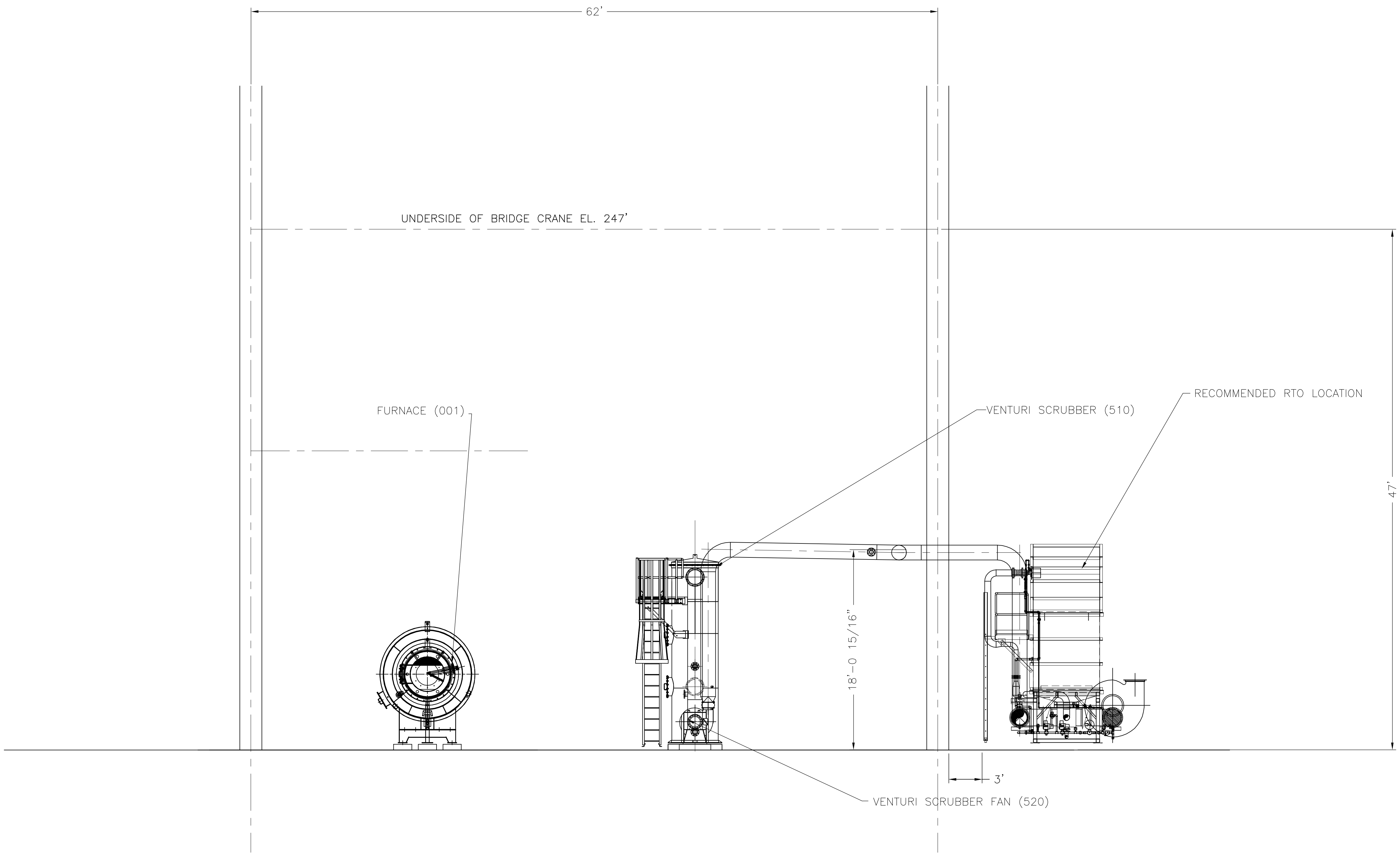
PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

ANDRITZ
ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: DAN	DATE: 5/12/10
CHECKED BY:	DATE:
APPROVED BY:	DATE:
SCALE: 3/16"=1'-0"	FILE ME303
SIZE	DDS40
JOB NAME	ROTARY DRYER SYSTEM
TITLE	DRYER AREA SECTION C-C
PROJECT NUMBER	
DRAWING NUMBER	ME-303
REV	A
SHEET	1 OF 1

REV | REVISION | DATE

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



D SECTION D-D

PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

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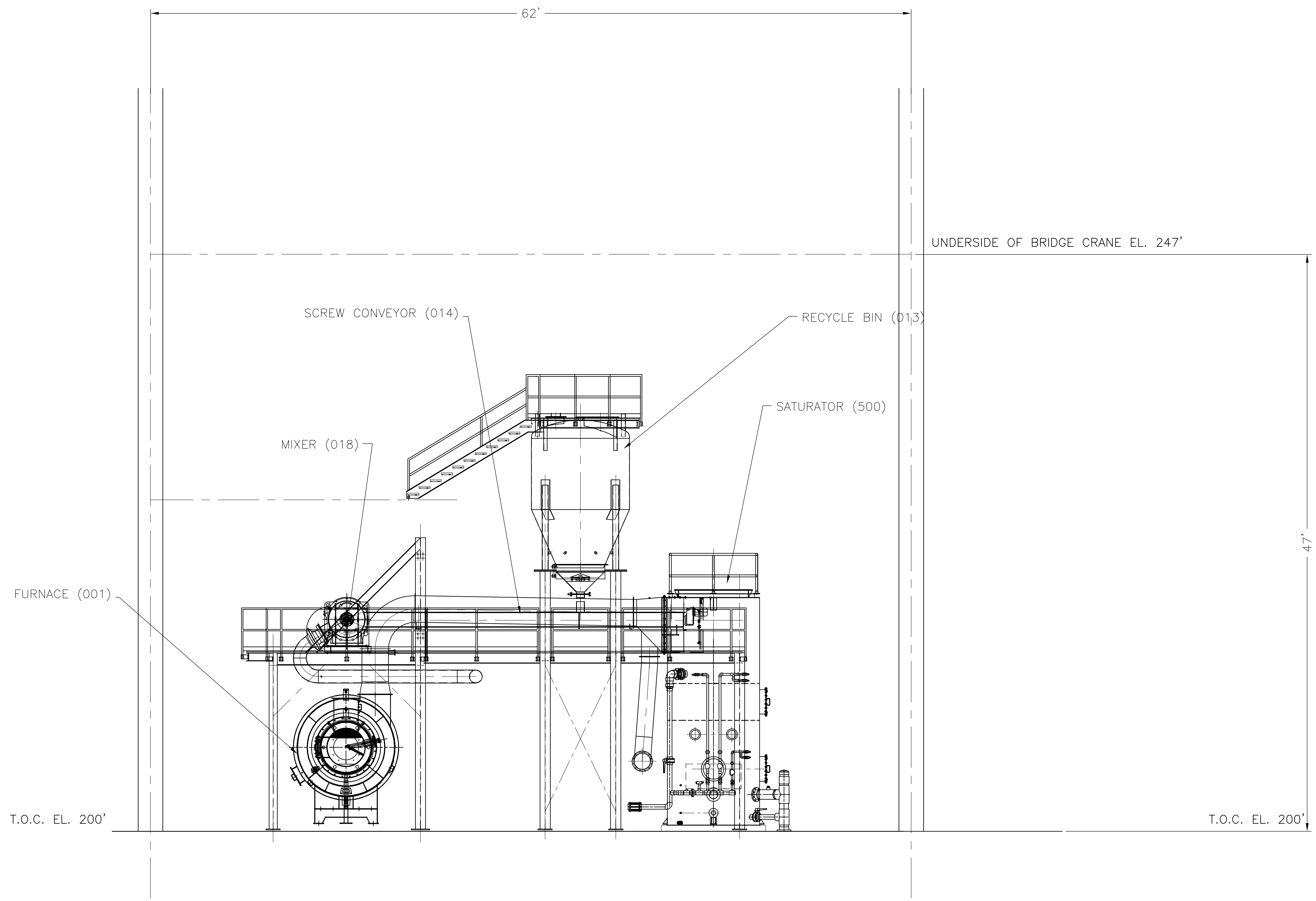
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: DAN — DATE: 5/12/10
CHECKED BY: — DATE:
APPROVED BY: — DATE:
SCALE: 3/16"=1'-0" — FILE: ME304
SIZE: DDS40

JOB NAME: ROTARY DRYER SYSTEM
TITLE: DRYER AREA SECTION D-D
PROJECT NUMBER
DRAWING NUMBER: ME-304 REV: A
SHEET 1 OF 1

REV	REVISION	DATE

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



E SECTION E-E

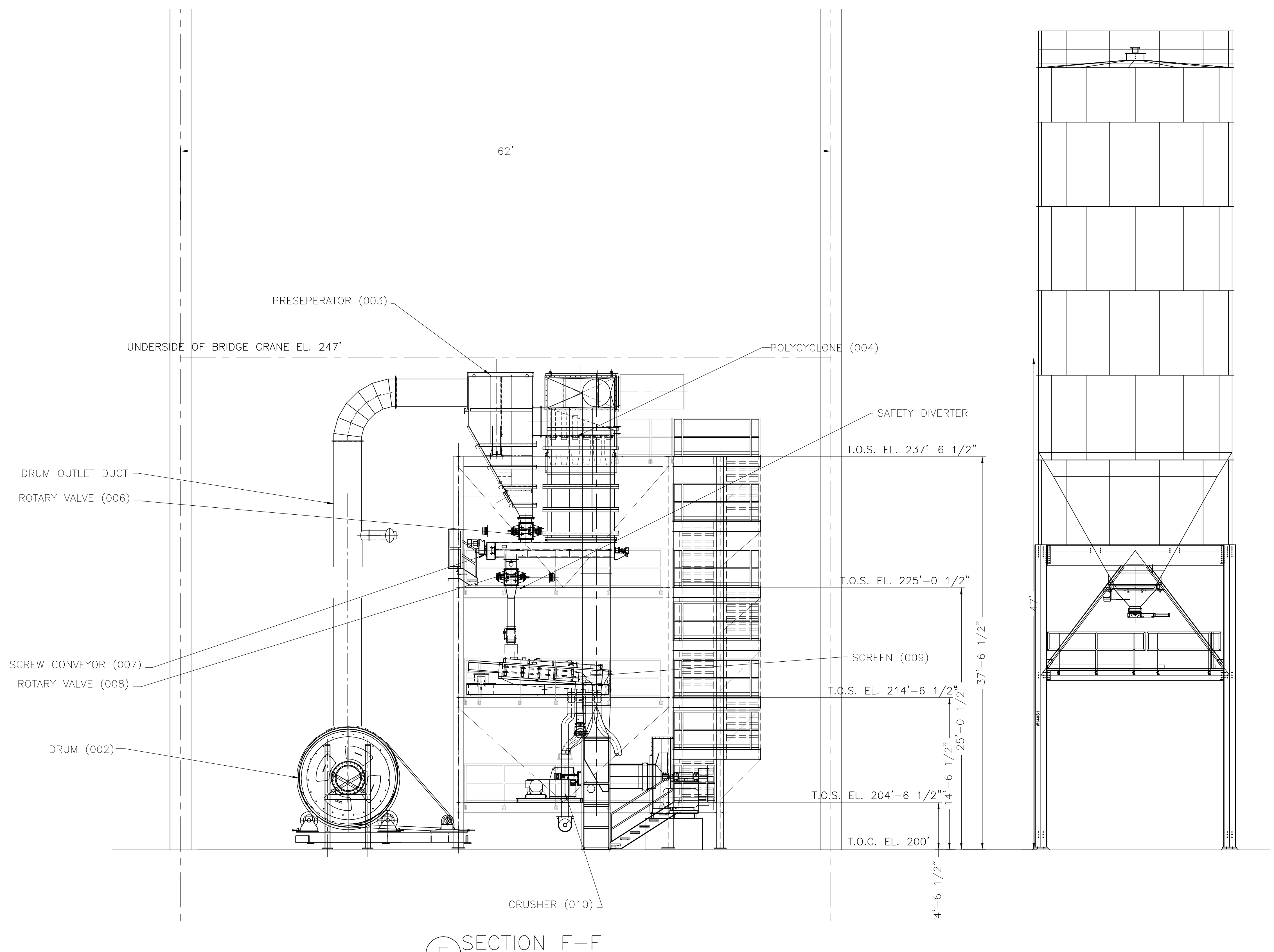
PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

ANDRITZ
ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: DAN	DATE: 5/12/10
CHECKED BY:	DATE:
APPROVED BY:	DATE:
SCALE: 3/16"=1'-0"	FILE ME305
SIZE	DDS40
JOB NAME	ROTARY DRYER SYSTEM
TITLE	DRYER AREA SECTION E-E
PROJECT NUMBER	
DRAWING NUMBER	ME-305
REV	A
SHEET	1 OF 1

REV	REVISION	DATE

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



PRELIMINARY DRAWINGS
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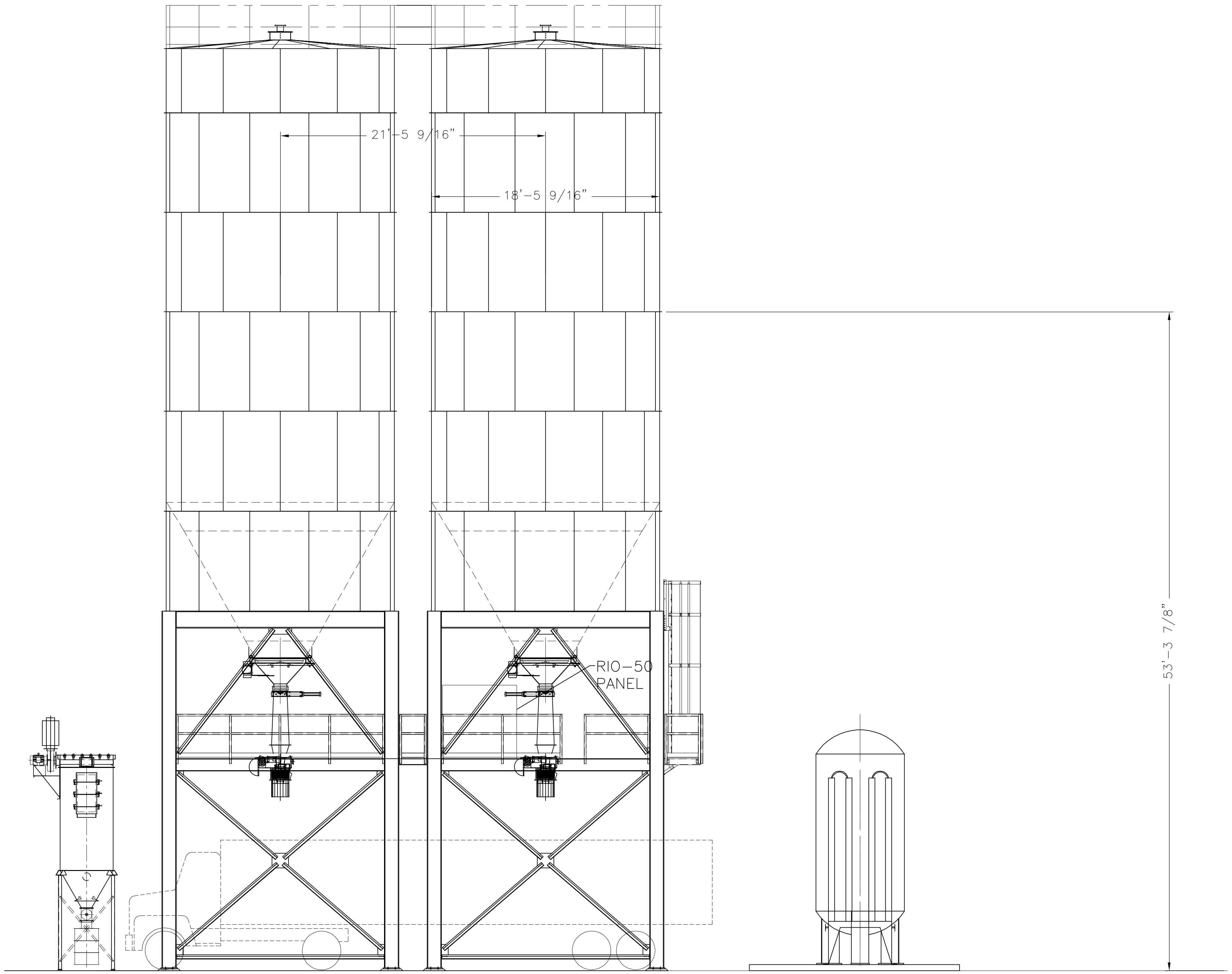
(817) 465-5611

DRAWN BY: DAN	DATE: 5/12/10
CHECKED BY:	DATE:
APPROVED BY:	DATE:
SCALE: 3/16"=1'-0"	FILE: ME306
SIZE	DDS40
JOB NAME	ROTARY DRYER SYSTEM
TITLE	DRYER AREA SECTION F-F
PROJECT NUMBER	
DRAWING NUMBER	ME-306
REV	A
SHEET 1 OF 1	

REV | REVISION | DATE

NOTES:
1. THIS DRAWING IDENTIFIES THE APPROXIMATE LAYOUT FOR THE ANDRITZ DDS-40 DRUM DRYING SYSTEM.



G SECTION G-G

ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

PRELIMINARY DRAWINGS
FOR REFERENCE ONLY

DRAWN BY: DAN	DATE: 4/22/10
CHECKED BY:	DATE:
APPROVED BY:	DATE:
SCALE: 3/16"=1'-0"	FILE ME307
SIZE	DDS40
JOB NAME	ROTARY DRYER SYSTEM
TITLE	SILO AREA SECTION G-G
PROJECT NUMBER	
DRAWING NUMBER	ME-307
REV	A
SHEET	1 OF 1