**Beyond Plastics • Beyond Toxics • Breathe Free Detroit**
**Blue Water Baltimore • California Communities Against Toxics**
**Chesapeake Climate Action Network • Clean Air Action Network of Glenn Falls**
**Clean Air Council • CT Coalition for Economic and Environmental Justice**
**Durham Environment Watch • Earthjustice • Environmental Integrity Project**
**Global Alliance for Incinerator Alternatives • Ironbound Community Corporation**
**The Minnesota Environmental Justice Table**
**South Baltimore Community Land Trust • Zero Waste Ithaca**

June 21, 2022

*Submitted online via Federal eRulemaking Portal at https:/www.regulations.gov/*
Administrator Michael Regan
U.S. Environmental Protection Agency

RE: Public Comments on Docket ID No. EPA–HQ–OAR–2021–0668, Federal Implementation Plan Addressing Regional Ozone Transport for the 2015 Ozone National Ambient Air Quality Standard; Proposed Rule, 87 Fed. Reg. 20,036 (April 6, 2022)

Dear Administrator Regan:

The undersigned groups ("Commenters") write to respectfully urge the U.S. Environmental Protection Agency ("EPA") to establish new pollution reduction requirements for municipal solid waste combustor units ("MWCs" or "incinerators") in its final rule addressing the federal implementation plan for interstate ozone transport. Many of our organizations have been working to reduce pollution from incinerators and promote sustainable waste management models for years if not decades. We appreciate the opportunity to submit these comments.[1]

## I. Background

In EPA's proposed rule, it requests comment on whether the final rule should include NOx limits for incinerators in states that cause or contribute to downwind ozone problems. [2] The ten states that EPA has identified as falling into this category are listed below, although more states may be subject to this requirement if EPA re-evaluates certain assumptions and omissions on which its analysis is based.

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[1] These comments are substantively identical to the Municipal Waste Combustors section in the longer set of comments submitted by a coalition of not-for-profit organizations addressing multiple aspects of the proposed rule.
[2] EPA, Federal Implementation Plan Addressing Regional Ozone Transport for the 2015 Ozone National Ambient Air Quality Standard, Proposed Rule, 87 Fed. Reg. 20036, 20086 (April 6, 2022).

| Table 1: States Potentially Subject to Requirements per EPA Analysis[3] | |
|---|---|
| California | New Jersey |
| Indiana | New York |
| Maryland | Oregon |
| Michigan | Pennsylvania |
| Minnesota | Virginia |

EPA also poses certain questions about what limit should be imposed, how record-keeping and reporting should be handled, and other matters. Commenters address each of these questions below.

## II. EPA Should Establish Limits for Incinerators in the Final Rule

EPA should require NOx reductions from incinerators in the final rule. These facilities emit high amounts of NOx, with large MWCs producing more NOx on average than even coal plants per unit of energy generated, and can achieve far lower NOx limits than the limits to which most facilities are currently subject. In addition, MWCs are often sited in economically marginalized communities and communities of color, subjecting residents of those neighborhoods to toxic emissions like lead, mercury, and dioxin in addition to NOx. Finally, large MWCs are already equipped with continuous emissions monitors for NOx, reducing one aspect of the cost of complying with new standards under a final EPA rule.

### A. Incinerators are Very Large NOx Emitters

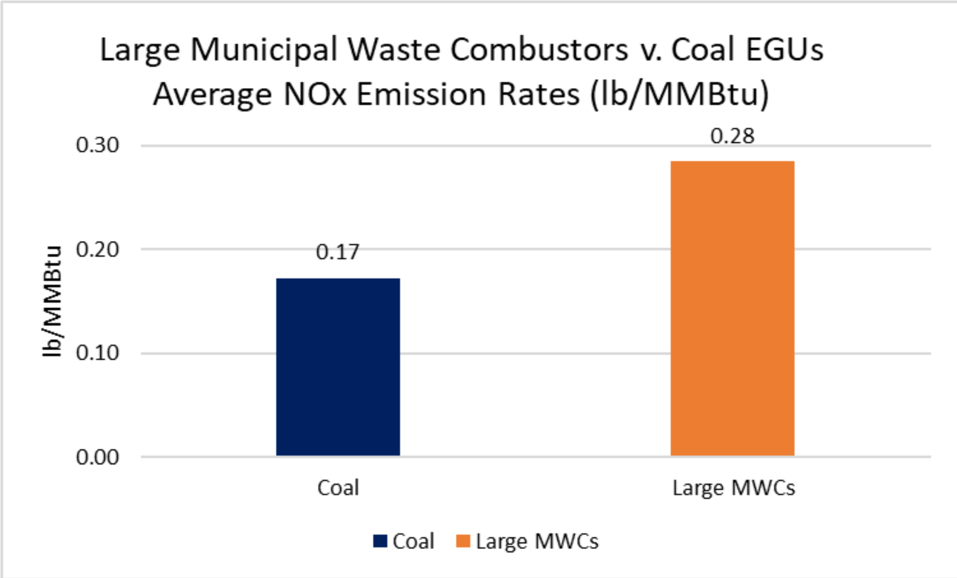
Multiple analyses have shown that incinerators emit more NOx than coal plants per output generated (based on either megawatt-hours generated or heat input).[4] In 2017, NEI data shows that incinerators emitted about 65% more NOx per unit of heat input than coal-fired electrical generating units ("EGUs"), with incinerators producing 0.28 lb/MMBtu of NOx compared with 0.17 lb/MMBtu NOx from coal plants.[5] This is illustrated in Figure 1 below.

[3] EPA, Technical Support Document (TSD) for the Proposed Rule, Non-EGU TSD (hereinafter "Non-EGU TSD") at 82-83.

[4] *See, e.g.* Environmental Integrity Project, Waste-to-Energy: Dirtying Maryland's Air by Seeking a Quick Fix on Renewable Energy? October 2011, at 6, https://environmentalintegrity.org/wp-content/uploads/2016/11/FINALWTEINCINERATORREPORT-101111.pdf.

[5] Emission rates were calculated for incinerators and coal-fired power plants using data from EPA's 2017 National Emission Inventory (NOx emissions) and the U.S. Energy Information Administration (EIA's) 923 Monthly Generation and Fuel Consumption Report. The analysis includes data from 53 incinerators and 235 coal-fired power plants. We excluded facilities if less than 90 percent of their net generation was attributable to either municipal solid waste or coal, based on the fuel type reported in EIA, if no NOx emission data was available, if the facility is a combined heat and power plant (i.e. produces both electricity and salable steam), or if the facility retired before the end of 2017. Some operators report facility data to NEI and EIA differently. For example, the Fort Smallwood EGU complex in Maryland is a single facility in NEI but reported separately as Brandon Shores and H A Wagner in EIA. In these cases, we combined fuel consumption and net generation, and calculated a collective emission rate.

**Figure 1**




In fact, in many of the nine transport states with both incinerators and EGU emissions budgets, NOx emissions from incinerators equate to a significant percentage of – or even more than – the EGU emission budgets. Comparing 2017 ozone season incinerator emission data from EPA's Non-EGU TSD[6] with the Proposed Rule's 2023 EGU emissions budgets,[7] New Jersey has *higher* MWC emissions than its entire EGU emission budget, while New York and Maryland have MWC emissions that exceed over half of their EGU emission budgets. By 2026, if EGU emissions reduce under the rule but incinerator emissions remain constant, an additional three states (Minnesota, Pennsylvania, and Virginia) would have incinerator emissions of 20-37% of their EGU emission budgets.

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[6] Non-EGU TSD at 82–83 tbl.8. Commenters have not conducted a comprehensive review of the information presented in Table 8, but we have noticed at least one item that requires correction. The Detroit Renewable Power facility in Michigan ceased operation in 2019. See, e.g., Aguilar, Louis, et. Al. *Detroit's controversial incinerator permanently shut down*, Detroit News, March 28, 2019, https://www.detroitnews.com/story/news/local/detroit-city/2019/03/27/detroits-controversial-incinerator-permanently-shutting-down-today/3287589002.

[7] 87 Fed. Reg. at 20044 tbl.I.B-1.

| Table 2: MWC Emissions Compared to EGU Emission Budgets | | | | |
|---|---|---|---|---|
| | **2017 MWC NOx Emissions (tons)** | **Estimated 2017 Ozone Season MWC NOx Emissions* (tons)** | **2023 Ozone Season EGU Emission Budget (tons)** | **2026 Ozone Season EGU Emission Budget (tons)** |
| **CA** | 654.5 | 268.8 | (no EGU budget) | (no EGU budget) |
| **IN** | 1,122.0 | 467.5 | 11,151 | 7,791 |
| **MD** | 1,542.9 | 642.9 | 1,187 | 1,189 |
| **MI** | 1,554.4 | 647.7 | 10,718 | 6,114 |
| **MN** | 2,279.7 | 949.9 | 3,921 | 2,536 |
| **NJ** | 2,162.1 | 900.9 | 799 | 799 |
| **NY** | 4,679.4 | 1,949.7 | 3,763 | 3,238 |
| **OK** | 518.5 | 216.0 | 10,265 | 4,275 |
| **PA** | 3,759 | 1,491.2 | 8,855 | 6,819 |
| **VA** | 2,071.7 | 863.2 | 3,090 | 2,567 |

* 2017 Ozone Season MWC NOx Emissions estimated by multiplying 2017 MWC NOx Emissions by 5/12.

### B. MWCs Harm Environmental Justice Communities

In addition to NOx, MWCs emit large amounts of health-harming toxic pollutants like lead, mercury, and dioxin into the air, often in economically marginalized communities or communities of color.

A 2019 report by the Tishman Environment and Design Center at The New School found that 79% of U.S. municipal solid waste incinerators are located in environmental justice communities, and that between 67% and 83% of the twelve incinerators that emit the most nitrogen oxides, sulfur dioxide, lead, mercury, particulate matter, and carbon monoxide are located in environmental justice communities, depending on the pollutant.[8]

MWCs are also recognized as large and problematic polluters within communities and states that house incinerators, including the ten states that house MWCs that EPA has identified as linked to downwind ozone impacts. In Maryland, the state's two large MWCs emit substantially more mercury per unit of energy generated than its largest coal-burning plants. In 2020, the Baltimore City large MWC emitted mercury at a rate 37 times higher than that of the average of the state's largest coal and gas-burning plants, while the Montgomery County large MWC emitted mercury at a rate 11 times higher than the fossil fuel-fired plants.[9] The large MWCs in the environmental justice communities of Newark and Camden, New Jersey, are the

[8] Ana Isabel Baptista & Adrienne Perovich, *U.S. Municipal Solid Waste Incinerators: An Industry in Decline* at 15 & App. E, Tishman Env't and Design Ctr. (May 2019), https://static1.squarespace.com/static/5d14dab43967cc000179f3d2/t/5d5c4bea0d59ad00012d220e/1566329840732/CR_GaiaReportFinal_05.21.pdf.

[9] Environmental Integrity Project, Testimony to Maryland House Economic Matters Committee in Support of HB11 at 1, https://environmentalintegrity.org/wp-content/uploads/2022/05/FINAL-EIP-2022-Testimony.pdf.

largest stationary-source emitters of NOx, PM2.5, HCl, lead, and mercury in their respective counties.[10]

### C. EPA's Rule Must Not Arbitrarily Fail to Regulate MWCs

EPA's failure to include limits for MWCs in its proposed rule is the result of the agency's arbitrary exclusion of MWCs from its screening analysis of non-EGUs. There is no basis for this exclusion, given the high NOx emissions from MWCs, and EPA must rectify this lapse by including limits for MWCs in the final rule. Further, EPA should not arbitrarily leave small MWCs – those with a waste burning capacity under 250 tons per day – unregulated. EPA should set NOx limits in the final rule for small MWCs except those whose operators can demonstrate the infeasibility of meeting the limit.

i. EPA Has Arbitrarily Excluded MWCs from its Screening Assessment

EPA's unexplained, unwarranted exclusion of incinerators from its Screening Assessment – and therefore, from any proposed regulation in the proposed rule – is arbitrary, and the final rule must assess and regulate incinerator emissions. EPA's threshold criteria for considering a non-EGU industry sector in its Screening Assessment is that the sector includes "emissions units that emit greater than 100 tons per year (tpy) of NOx" and that these are "uncontrolled sources or sources that could be better controlled at a reasonable cost."[11] Incinerators meet both these criteria. Over 90% of the incinerators in transport states emit over 100 tpy of NOx, with a per-facility average of 473 tpy of emissions.[12] And the proposed rule cites findings by the Ozone Transport Commission ("OTC") that incinerators could be better controlled at costs well within the proposed rule's cost effectiveness threshold.[13] Incinerators thus easily meet EPA's threshold criteria for the screening assessment.

But instead of analyzing incinerators in the Screening Assessment, EPA baselessly excludes this entire industry from the assessment. The Screening Assessment's only mention of incinerators is an introductory footnote that "[t]he non-EGU 'sector' . . . does not include municipal waste combustors (MWC), cogeneration units, or <25 MW EGUs."[14] EPA provides no explanation of why it entirely excludes an industry that the proposed rule admits "emit[s] substantial amounts of NOx." 87 Fed. Reg. at 20085. To the extent that the footnote suggests that EPA does not consider incinerators to be "non-EGUs" because many of them do produce electricity, that is no rationale given that EPA expressly excludes incinerators from its regulation

[10] Earthjustice & Vermont Law School Environmental Advocacy Clinic, *New Jersey's Dirty Secret: The Injustice of Incinerators and Trash Energy in New Jersey's Frontline Communities* at 9, https://earthjustice.org/sites/default/files/files/nj-incinerator-report_earthjustice-2021-02.pdf.
[11] 87 Fed. Reg. at 20083.
[12] Non-EGU TSD Table 8 (showing 39 of 43 incinerators with over 100 tpy of NOx emissions in 2017).
[13] 87 Fed. Reg. at 20086.
[14] Screening Assessment at 1 n.1.

of EGUs.[15] Just because incinerators share characteristics of both the EGU and non-EGU sectors does not mean that they can avoid regulation altogether.

Indeed, EPA's exclusion of incinerators from the Screening Assessment and from proposed regulation is particularly arbitrary given that incinerators emit *more* NOx than nearly all of the 41 other non-EGU industries that EPA *did* screen and consider. EPA's supporting documents show that incinerators in transport states emit more NOx than what EPA predicts all but seven of the 41 analyzed industry categories emit.[16] And looking at the absolute number of facilities in transport states that emit 100 tpy or more of NOx, incinerators outnumber other categories of facilities for all but five of the other industries analyzed.[17] It is arbitrary for EPA to fail to propose MWC emission limits when it did propose limits on industries with much less NOx impact – EPA must rectify this by including incinerator limits in the final rule.

ii. EPA Should Not Arbitrarily Fail to Set Limits for Small MWCs

EPA should set NOx limits for all MWCs in transport states, including those that do not meet the 250 ton-per-day capacity threshold for large MWCs from CAA Section 129.[18] Congress's choice of capacity threshold between large and small MWCs in Section 129 has no bearing on whether an incinerator must be regulated under the CAA Good Neighbor Provision. And EPA has not promulgated *any* enforceable NOx emission limit for facilities below this threshold under Section 129,[19] so NOx from these smaller facilities will continue to be entirely unregulated unless EPA imposes an emission limit in the final rule. Such an emission limit would increase NOx reductions and capture MWC units with capacity just below the threshold, like New York's MacArthur Waste-to-Energy facility, which has a capacity of 242.2 tons per day.[20]

Under Commenters' recommended approach, described in Section II.E below, the operators of smaller MWCs will have the opportunity to demonstrate that they are unable to meet

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[15] *See* 87 Fed. Reg. at 20085 ("The electrical output of MWCs is relatively small compared to the EGUs that will be regulated per the proposed requirements of Section VII.B of this proposal, with most MWCs having an electrical output capacity of less than 25 MW.").
[16] Compare Non-EGU TSD at 81 ("[I]n 2017[,] 20,344 tons of NOx were emitted from MWCs in the ten transport states containing them," then multiply 20,344 tons by 5/12 to estimate the 5 months of ozone season emissions, yielding 8,476.7 tons), with Screening Assessment at 25 tbl.A-3 (showing only seven industries with "ozone season emissions" in 2023 above 8,476.7 tons).
[17] Compare Non-EGU TSD at 82-83 tbl.8 (listing 39 incinerators in transport states with emissions above 100 tpy) with Screening Assessment at 25 tbl.A-3 (showing only 5 of the 41 industries listed as having more than 39 facilities in transport states that emit over 100 tpy of NOx).
[18] *See* 42 U.S.C. § 7429(a)(1)(B), (C).
[19] "[W]aste combustion plants with an aggregate plant combustion capacity less than or equal to 250 tons per day of municipal solid waste . . . do not have a nitrogen oxides emission limit." 40 C.F.R. § 60.1045(a)(2), (b)(1). "No monitoring, testing, recordkeeping, or reporting is required to demonstrate compliance with the nitrogen oxides limit for [these] units." 40 C.F.R. Pt. 60, Subpt. AAAA, Tbl. 1; *see also id.* Pt. 60, Subpt. BBBB, Tbl. 4 (same).
[20] Ozone Transport Commission Stationary and Area Sources Committee, Municipal Waste Combustor Workgroup Report, Revised April 2022, at 40, https://otcair.org/upload/Documents/Reports/MWC%20Report_revised%2020220425.pdf ("Final OTC MWC Report").
[20] *Id.*

the limit at or below EPA's final cost-effectiveness threshold and to accept the lowest possible limit based on that threshold.

### D. The Final Rule Should Set a MWC NOx Limit of 50 ppm on a 24-Hour Average

EPA must set a 24-hour NOx emission limit of 50 parts per million dry volume @ 7% O2 ("ppm") for MWCs based on selective catalytic reduction technology, which is the technology needed to ensure this high-emitting sector stops contributing to downwind ozone pollution. In the alternative, EPA should set a 24-hour emission limit no higher than 110 ppm based on less effective, though still widely available, control technology. It has been demonstrated that many kinds of MWCs can meet a 24-hour limit of 110 ppm by operating cost-effective NOx controls.

#### i. It is Critical that EPA Set a Short-Term Limit for Incinerators

As a threshold matter, Commenters consider it imperative that EPA establish a NOx limit for MWCs that is measured on an averaging period of 24 hours or shorter. As described in more detail in the sections below, it has been well demonstrated that almost all large MWCs can meet a much more stringent 24-hour limit than the one to which most units are currently subject. A 24-hour limit will help to reduce the likelihood that the substantial NOx emissions from MWCs will contribute to a spike in ozone, which is measured on an eight-hour average for the 2015 ozone standard. This is particularly important for MWCs to prevent dangerous, shorter-term spikes in emissions.

#### ii. EPA Should Establish A 24-Hour NOx Limit of 50 ppm for MWCs

EPA should establish a 24-hour NOx limit of 50 ppm based on selective catalytic reduction ("SCR") technology for incinerators. SCR is a widely available technology that, as the proposed rule notes, already is in use in 60% of the coal fleet, and has been considered Best Available Control Technology ("BACT") for decades.[21] The OTC's revised Municipal Waste Combustor Workgroup Report ("Final OTC MWC Report") – whose prior version is discussed in the proposed rule – notes that the Palm Beach Renewable Energy Facility uses SCR and has a permitted emission limit of 50 ppm – both of which were considered BACT during the permitting process in 2010.[22] The Final OTC MWC Report also notes that analyses of installing SCR at three other existing MWCs also assumed emission rates of 50 ppm.[23]

The Final OTC MWC Report presents results from third-party studies of SCR installation and use costs of $10,296/ton to $12,779/ton (Wheelabrator Baltimore), $15,898/ton (Covanta Fairfax), and $31,445/ton (Covanta Alexandria/Arlington).[24] While these estimates vary, the lowest estimate (Wheelabrator Baltimore) is most analogous the $11,000/ton weighted-average cost for new SCRs for coal units that EPA finds acceptable in the proposed rule.[25] As described in more detail below, the accuracy of the Wheelabrator Baltimore estimate appears to depend on

[21] 87 Fed. Reg. at 20,080.
[22] Final OTC MWC Report at 60-61.
[23] *Id.*
[24] *Id.*
[25] 87 Fed. Reg. at 20,081.

what the cost is of operating the current control system on the Baltimore incinerator and we request that EPA ask for information to verify that cost.

These SCR emission controls are necessary to prevent interstate ozone transport, especially from upwind states like New Jersey where incinerators make up a significant percentage of NOx emissions but where the rule, as proposed, would result in little to no NOx emission reductions. EPA predicts that New Jersey will continue to significantly contribute to downwind receptors in 2026, with contributions of up to 8.54ppb for downwind nonattainment receptors and 5.47ppb to downwind maintenance receptors that year, higher than the contributions of all but a handful of other states.[26] Yet EPA does not propose measures necessary to reduce this contribution, requiring no reductions from New Jersey's non-EGU sector and no reductions in the state's EGU emission budget after 2023.[27] EPA should therefore look to emission reductions from incinerators to eliminate New Jersey's significant contributions to interstate ozone. But all four of New Jersey's currently operating incinerators are already equipped with SNCR systems, and the state's two largest incinerators – responsible for nearly 70% of the state's incinerator NOx emissions[28] – are equipped with the additional Low NOx systems that are the basis of the 100 ppmvd (24-hour) limit EPA raised in the proposed rule.[29] Thus, for the rule to make meaningful reductions in – let alone eliminate – New Jersey's significant 8.54ppb contribution to downwind receptors, EPA must go beyond the technology already in place in New Jersey's largest incinerators, and instead require SCR technology and a 50ppm (24-hour) limit.

EPA cannot discount SCR technology for incinerators merely because it may exceed EPA's cost-effectiveness threshold for non-EGUs. That threshold was determined by finding the "knee in the curve" of a plot of various control measures for EPA's Tier 1 and Tier 2 industries *only*, and so did not consider cost estimates specific to the incinerator industry.[30] And as noted above, EPA has cautioned that this knee in the curve "is not on its own a justification for not requiring reductions beyond that point in the cost curve," and EPA has previously required controls that exceeded this knee in the curve.[31] Indeed, states subject to this Rule have their own cost-effectiveness thresholds of up to \$18,983/ton $NO_x$,[32] which are more than high enough to accommodate SCR costs for incinerators.

iii. In the Alternative, EPA Should Set a 24-Hour NOx Limit of 110 ppm for MWCs

Assuming that EPA does not require a 50 ppm limit based on SCR – which it should do – EPA should require that MWCs meet a 24-hour NOx limit of no more than 110 ppm. Recent

[26] 87 Fed. Reg. at 20,071 tbl.V.E.1-2.
[27] See tbl. I.B-1 and tbl. VI.C.2-2.
[28] This percentage calculated using 2017 NOx emission data from Non-EGU TSD Table 8 for all New Jersey MWCs except the Covanta Warren Energy Resource Center, which is no longer operating. See Steven Novak, Covanta has shut down its Warren County trash incinerator. But it might not be permanent., Lehighvalley.com, Apr. 4, 2019, https://www.lehighvalleylive.com/warren-county/2019/04/covanta-has-shut-down-its-warren-county-trash-incinerator-but-it-might-not-be-permanent.html.
[29] *See* Final OTC MWC Report App.B at 35-36.
[30] *See* Non-EGU Screening Assessment at 4.
[31] *See* supra Section X.A (quoting 86 Fed. Reg. at 23,107).
[32] *See* supra Section X.B.

studies have shown that there are a variety of technologies that can help a wide range of MWC boiler types achieve this limit at costs that are significantly below the $7,500/ton cost effectiveness threshold in EPA's proposed rule.

*1. Covanta facilities*

As noted in the Final OTC MWC Report, there are eight Covanta large MWC units already subject to a 24-hour limit of 110 ppm, with significantly different size, boiler type, and manufacturers. These facilities have achieved this by installing Covanta's patented Low NOx system on facilities in combination with SNCR.[33] Two of these are Covanta large MWCs located in Virginia, which were required to meet limits of 110 ppm on a 24-hour basis and 90 ppm on an annual average pursuant to the Virginia Department of Environmental Quality's ("VADEQ's") decision regarding Reasonably Available Control Technology ("RACT") requirements.[34] The cost-effectiveness of meeting the new 110 ppm daily limits was estimated by OTC, based on information submitted during Virginia's RACT process, as $3,204 per ton for the Fairfax facility and $4,639 per ton for the Alexandria/Arlington facility.[35]

In addition, though it is not currently subject to a 110 ppm permit limit, the Montgomery County Resource Recovery Facility ("MCRRF") in Maryland also operates Covanta's Low NOx technology installed in combination with SNCR. The Low NOx system was added in 2008-2010. As shown in Table 1 below, this reduction in NOx emissions was achieved while plant operations remained relatively constant.

**Table 3: MCRRF $NO_x$ Emissions and Operating Data 2006-2015**[36]

| **Year** | **$NO_x$ emissions** (tons) | **Waste processed** (tons) | **% capacity** (waste burning) | **Power generated** (megawatt hours) |
|---|---|---|---|---|
| **2006** | 1,041 | 620,666 | 94% | 371,971 |
| **2007** | 1,009 | 578,804 | 88% | 343,955 |
| **2008** | 998 | 573,293 | 87% | 331,055 |
| **2009** | 554 | 527,623 | 80% | 282,170 |
| **2010** | 499 | 551,670 | 84% | 303,075 |
| **2011** | 512 | 556,266 | 85% | 308,150 |
| **2012** | 479 | 544,647 | 83% | 310,008 |
| **2013** | 388 | 555,716 | 85% | 312,539 |
| **2014** | 427 | Not available | Not available | 315,450 |
| **2015** | 441 | 599,250 | 91% | Not available |

[33] Final OTC MWC Report at 16.
[34] *See* VADEQ February 8, 2019 letters to Covanta with NOx RACT permit conditions attached (Attachment A; *see also* EPA, Approval and Promulgation of Air Quality Implementation Plans; Virginia; Source-Specific Reasonably Available Control Technology Determinations for 2008 Ozone National Ambient Air Quality Standard, 84 Fed. Reg. 67196, 67197 (Dec. 9.2019).
[35] Final OTC MWC Report at 20,21.
[36] Emissions data from Maryland Emissions Inventory, obtained by the Environmental Integrity Project ("EIP") through public record requests. EIP will provide the data to EPA upon request. Capacity and power generation data from Northeast Maryland Power Waste Disposal Authority ("NMWDA") website at http://nmwda.org/montgomery-county/,except for 2014 power generation data from U.S. Energy Information Administration ("EIA") and 2015

MCRRF's annual average $NO_x$ emissions from 2006-2008 were 1,016 tons per year. After the installation of the new Low $NO_x$ controls, during the period from 2009 through 2011, average $NO_x$ emissions were 522 tons per year. This is an average reduction of 494 tons per year or 48.6% of emissions. EPA also noted at the time that the technology "demonstrated a reduction of NOx emissions by approximately 50 percent from pre-installation levels."[37]

Further, based on current NOx continuous emission monitoring system ("CEMS") data from the MCRRF, OTC states conclusively that this facility can meet a 24-hour NOx limit of 110 ppm, explaining:

> Maryland's NOx RACT also required a NOx 30-day rolling average emission rate of 105 ppmvd @7% O2 to be met beginning on May 1, 2020. Since that time, the peak 24-hour average recorded has been on the order of 103 ppmvd @7% O2. <u>The facility is capable, and further demonstrates, meeting a 110 ppmvd 24-hour limit</u>. Information from a Montgomery County Resource Recovery NOx optimization study found that ammonia slip is below 5 ppm for all units with LNTM technology with SNCR and with NOx emissions of 66 ppm and higher.[38]

If EPA wishes to review the NOx CEMS data from MCRRF itself, that data is available online.[39]

During the OTC process, Covanta representatives submitted comments noting that the Low NOx technology cannot be installed on certain of its facilities, including those that use Aireal grate technology, those that operate RFD units, and those that use rotary combustor units.[40]

However, even incinerators that don't use Low-NOx technology may be able to meet the 110 ppm limit with SNCR only. Covanta's Delaware Valley Resource Recovery Facility in Pennsylvania, for example, uses rotary combustors but has no NOx controls whatsoever. Nevertheless, its per-unit maximum 24-hour NOx emissions over the past 6 years ranged from 122 ppm to 172.5 ppm, so 110 ppm may be achievable with the installation of SNCR or other cost-efficient NOx controls. Covanta has already committed to a voluntary trial of SNCR at one of the units on this incinerator. [41]

In summary, it appears that the majority of Covanta units should be able to achieve a 24-hour limit of 110 ppm and those that are legitimately unable to meet this limit should be afforded

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waste processing data from Maryland Department of the Environment PowerPoint presentation dated August 30, 2016 on NOx RACT for Large MWCs.

[37] U.S. EPA, Clean Air Excellence Award Recipients: Year 2014 at 1, https://www.epa.gov/sites/production/files/2015-06/documents/clean_air_excellence_award_recipients_year_2014.pdf .

[38] Final OTC MWC Report at 15 (emphasis added).

[39] Montgomery County Department of Environmental Protection, Emissions Data Detail – Resource Recovery Facility, https://www montgomerycountymd.gov/sws/facilities/rrf/cem-detail.html.

[40] Excerpt from Comments from OTC MWC Stakeholder and OTC Responses (hereinafter "OTC Responses") at 7. (Attachment B). In OTC's recap, it appears that Covanta stated that two of its Pennsylvania facilities use rotary technology, though the Final OTC MWC Report identifies only one facility in PA that uses this boiler type. *See* Final OTC MWC Report at 37

[41] *Id*. at 8.

the opportunity to submit facility-specific information demonstrating that the limit is infeasible for the facility in question.

*2. Babcock Power study on Wheelabrator Baltimore facility*

Further, a report completed in 2020 assessing options for reducing NOx at the Wheelabrator incinerator in Baltimore City demonstrates that Covanta-operated facilities are not the only ones that can achieve a 110 ppm NOx limit on a 24 hour basis.[42]

In this study, vendors evaluated the control efficiency and costs of several technology options for reducing NOx at the Wheelabrator facility in Baltimore. The cost-effectiveness of the technologies was summarized in the Final OTC MWC Report issued in April 2022 and includes a technology capable of achieving a 24-hour limit of 110 ppm at a cost of either $3,883/ton or around $6,000/ton depending on which set of assumptions is used, as discussed in more detail below.[43]

Thus, there is ample evidence that multiple types of large MWCs can achieve a 24-hour limit of 110 pm at costs well below EPA's proposed cost-effectiveness threshold for non-EGUs of $7,500 per ton.

**E. Responses to Additional EPA Questions in Proposed Rule regarding Municipal Waste Combustors**

In addition to the comments above, Commenters provide the direct responses below to EPA's list of six questions about regulating MWC NOx in the proposed rule.[44]

> <u>EPA Question:</u> What NOx emissions limit and averaging time should MWCs be required to meet, and in particular should the EPA adopt emissions rates of 105 ppmvd on a 30-day averaging basis and 110 ppmvd on a 24-hour averaging basis?

Response:

As explained in detail in Section II.D above, EPA should prioritize a 24-hour NOx limit, and set this 24-hour limit at 50 ppm.

> <u>EPA Question:</u> What types of NOx control technology could be used to reduce NOx emissions at MWCs, and in particular should the EPA adopt the combustion control modifications made to units with previously installed SNCR identified by the MWC workgroup?

Response:

As explained in detail in Section II.D above, EPA should set emission limits based on assumed installation of SCR technology. SCR is widely used in the industrial sector and

[42] Waste to Energy NOx Feasibility Study Prepared for Wheelabrator Technologies Baltimore Waste to Energy, Baltimore, Maryland, BPE Project No. 100825 (February 20, 2020) (hereinafter "Babcock Power Study for Wheelabrator Baltimore Incinerator", Attachment C).

[43] Babcock Power Study for Wheelabrator Baltimore Incinerator at 22, 63. The cost identified in Table 8 on page 22 of the report is $6,159/ton. However, as described in more detail below, that table overestimates pollution control operating costs.

[44] 66 Fed. Reg. 20086.

currently installed at the Palm Beach Renewable Energy Facility to meet a 50 ppm NOx emission limit.

> EPA Question: Whether there is information that would call into question the OTC workgroup's estimated cost of controls for reducing NOx emissions from MWCs of \$2900 to \$6600 per ton, and, assuming that range is accurate, whether there is any justification for not requiring these controls in light of their relative cost-effectiveness and total level of reductions available, which compare favorably with the proposed EGU and non-EGU control strategies?

Response:

There is no justification for failing to set limits for large MWCs that are at least as strong as the limits of 110 ppm on a 24-hour average and 105 ppm on a 30-day average that are identified in the OTC report so long as the operators of individual facilities are given the opportunity to submit facility-specific information demonstrating that a particular MWC is unable to meet the limit.

Commenters expect that industry may submit comments stating or implying that MWCs should not have to incur additional costs because of their ostensibly important role in energy and waste management systems. This is not correct. As explained above, as an energy source, large MWCs are more polluting than coal per unit of heat input for certain pollutants, including NOx. In addition, incineration should not be encouraged as a waste management approach. MWC industry representatives frequently claim that incineration is environmentally friendly because it avoids the generation of landfill methane emissions. This argument ignores that incinerators are themselves greenhouse-gas emitters,[45] not to mention emitters of various criteria pollutants and hazardous air pollutants, and generators of potentially toxic ash that itself must be appropriately disposed of at landfills. While reduction of landfill methane is extremely important, EPA must achieve this in other ways, specifically by ramping up programs for waste diversion and requiring improved emission control systems at landfills.

In addition, it appears that OTC overestimated the upper end of the cost-effectiveness range, based on existing materials, of achieving a 24-hour limit of 110 ppm. The upper end of the range for achieving this limit is based on the Babcock Power study on the Wheelabrator Baltimore facility. Using information from this report, OTC estimated in one table, Table 8, that the cost-effectiveness of achieving a 110 ppm limit on a 24-hour basis is \$6,159/ton.[46] However, this number improperly includes the entire cost of operating the technology associated with that limit, rather than the incremental cost of altering the current control system to achieve the lower limit.

A proper analysis would use the same baseline for calculating emission reductions and costs. In Table 8, emission reductions are calculated using a baseline emissions limit of 150 ppm on a 24-hour average, the limit to which the Baltimore incinerator has been subject since May 2019,[47] which is achieved using an SNCR system. The cost of operating this system in a manner that meets the baseline 150 ppm limit must be subtracted from the cost of operating technologies

[45] *See* U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018, at 2-3 (2020), https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf (noting incinerators emitted 11 million tons of carbon dioxide in 2018).
[46] Final OTC MWC Report at 22.
[47] COMAR 26.11.08.10(B).

to achieve further reductions. However, Table 8 incorporates the entire cost of operating the Advanced SNCR system associated with the 110 ppm limit.[48] This cost, $995,000 per year, is clearly identified in the original Babcock Power study as the entire cost, not the incremental cost, of operating Advanced SNCR.[49]

The only baseline cost information provided in the Babcock Power study is $695,000 for operating the existing SNCR. However, it is not clear from the Babcock Power study whether this cost is associated with a baseline 150 ppm or 135 ppm limit.[50] If this is the cost of meeting the current 150 ppm limit, then the cost-effectiveness table on page 63 of the Final OTC MWC Report is approximately correct. This table identifies a cost of $3,883 per ton of achieving a 110 ppm limit using Advanced SNCR.[51] If $695,000 is the operating cost of meeting a 135 ppm limit, then the incremental cost of going from 135 to 110 ppm using Advanced SNCR is about $6,067 per ton.[52]

We urge EPA to request additional information from the incinerator's owner, WIN Waste (formerly Wheelabrator) and/or Babcock Power, the company that performed the study, on the current costs of operating the SNCR system to achieve the 150 ppm limit. Commenters are also concerned about the capital costs estimated in the Babcock Power study for the Advanced SNCR technology associated with achieving 110 ppm and recommend that EPA request a breakdown of the capital costs for that technology. Commenters will also seek this information, particularly then baseline cost of operating the existing SNCR at the Baltimore incinerator, and will provide it to EPA if we obtain it.

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[48] *Id*.
[49] Babcock Power Study for Wheelabrator Baltimore Incinerator at 29.
[50] *Id.* at 15, 29.
[51] Final OTC MWC Report at 63.
[52] The table below is an altered version of Table 8 in the Final OTC MWC Report that incorporates incremental operating costs assuming the Existing SNCR costs identified in the Babcock Power Study are associated with a 135 ppm limit. Bolded values differ from those in Table 8 of the Final OTC MWC Report.

| | Advanced SNCR |
|---|---|
| Capital Costs | $8,665,162 |
| Annual Operating Costs | **$300,000** |
| Annualized Capital Costs | $817,930 |
| Projected Lifetime (yr) | 20 |
| Interest Rates (%) | 7% |
| Total Yearly Costs | **$1,117,930** |
| Base Case NOx (ppm) | **135** |
| Controlled NOx (ppm) | 110 |
| Estimated NOx Reduction Factor | **0.185** |
| Estimated NOx Reduction (%) | **18.5** |
| Baseline NOx Emission (tons/yr) | **993.38** |
| Projected Controlled NOx Emissions (tons/yr) | **809.38** |
| Emission Reduction (tons/yr) | **184** |
| **Cost effectiveness ($/ton)** | **$6,067** |

Lastly, if industry cites increases in urea costs as it did during the OTC process, we urge EPA to require information relating to current urea costs, as many facilities already operate SNCRs and incur costs for its use.

> EPA Question: If the final FIP includes emission reduction requirements for MWCs, should any mechanism be available by which a particular MWC source could seek to establish that meeting the required emission limits is not feasible?

Response:

Yes. MWC operators should be allowed to submit facility-specific information demonstrating that a particular MWC cannot meet the new limits at or below the cost-effectiveness threshold in EPA's final rule. If EPA, after evaluation of the materials, determines that the MWC at issue cannot meet the limit at that cost/ton, then the MWC should be required to meet the lowest 24-hour limit that *can* be achieved at the cost threshold.

Among other things, EPA should require an MWC operator who seeks to avoid the FIP limits to submit the following in order to demonstrate that the units cannot meet the limit: (1) costs of operating the current NOx control system, including current urea or ammonia usage; (2) NOx CEMS data showing trends over the last 5 years; (3) information supporting costs and effectiveness of installation of the controls discussed in the Babcock Power study; and (4) if insufficient room for new technology is offered as a reason for infeasibility, facility blueprints or schematics. In addition, to increase transparency, EPA should post online requests submitted by MWC operators for an EPA determination that it is infeasible to meet the FIP limit as well as EPA's determinations letters.

> EPA Question: Is there any evidence that retrofit of MWC emission controls would take longer to implement than the 2026 ozone season?

Response:

The information submitted with the Babcock Power study suggests the following retrofit schedules from the start of engineering through commissioning and shows that retrofit of MWC emission controls would not take longer to implement than the 2026 ozone season:

**Table 4: Technology Retrofit Schedules Based on Babcock Power Study**[53]

| **Control Technology** | **Schedule** |
|---|---|
| Optimizing Existing SNCR | 2 months |
| Flue Gas Recirculation (FGR) + Existing SNCR | 16 months |
| Advanced SNCR | 11 months |
| FGR + Advanced SNCR | 16 months |
| SCR | 18 to 26 months (depending on type) |

[53] Babcock Power Study, Appendix A-1 (Preliminary Schedule).

EPA Question: Would it be appropriate to rely on existing testing, monitoring, recordkeeping, and reporting requirements for MWCs under the applicable NSPS or other requirements?

Response:

All large MWCs are already required to use CEMS to demonstrate compliance with NOx limits.[54] This is yet another reason that EPA should require NOx reductions from this sector in the final rule.

EPA should improve electronic reporting requirements, however, beyond current requirements in the NSPS. An owner or operator of an MWC that is subject to a limit under the final rule should be required to report NOx CEMS data electronically at least annually to EPA's Compliance and Emissions Data Reporting Interface ("CEDRI") and any other database that EPA will utilize when considering revisions to the NSPS for large MWCs. In addition, MWC operators should be required to report NOx CEMS data to EPA's Clean Air Markets database, which will allow the public access to MWC CEMS data on a large scale for the first time.

Thank you for considering our comments.

Respectfully submitted,

Leah Kelly
Senior Attorney
Environmental Integrity Project **(National)**
lkelly@environmentalintegrity.org

Jonathan Smith
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Earthjustice **(National)**
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KT Andresky, Campaign Organizer
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Lisa Arkin, Executive Director
Beyond Toxics **(Oregon)**
Eugene, OR

Shashawnda Campbell
South Baltimore Community Land Trust **(Maryland)**
Baltimore, MD

Krystle D'Alencar
The Minnesota Environmental Justice Table **(Minnesota)**
Minneapolis, MN

Judith Enck, Former EPA Regional Administrator
President, Beyond Plastics (**National)**

[54] *See, e.g.*, 40 C.F.R. §§ 60.38b(a), 60.58b(b).

Bennington, VT

Jane Williams, Executive Director
California Communities Against Toxics **(California)**
Rosamond, CA

Tracy Frisch
Clean Air Action Network of Glenn Falls **(New York)**
Glenn Falls, NY

Anne Havemann, General Counsel
Chesapeake Climate Action Network **(Chesapeake Bay Regional)**
Takoma Park, MD

Yayoi Koizumi
Zero Waste Ithaca **(New York)**
Ithaca NY

Sharon Lewis, Executive Director
CT Coalition for Economic and Environmental Justice **(Connecticut)**
Hartford, CT

Maria Lopez-Nunez, Deputy Director of Organizing and Advocacy
Ironbound Community Corporation **(New Jersey)**
Newark, NJ

Joseph Otis Minott, Executive Director and Chief Counsel
Clean Air Council **(Pennsylvania)**
Philadelphia, PA

Kerry Meydam, Founder
Durham Environment Watch **(Canada)**
Courtice, Ontario

Alice Volpitta
Baltimore Harbor Waterkeeper **(Maryland)**
Blue Water Baltimore
Baltimore, MD

Monica Wilson, Associate Director of GAIA U.S.
Global Alliance for Incinerator Alternatives **(National/International)**
Berkeley, CA

# Attachment A

Virginia Department of Environmental Quality February 2019 Letters
Regarding Reasonably Available Control Technology ("RACT")
at Covanta Alexandria/Arlington and Fairfax facilities

*Commonwealth of Virginia*

*VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY*

NORTHERN REGIONAL OFFICE
13901 Crown Court, Woodbridge, Virginia 22193
(703)583-3800 FAX (703) 583-3821
www.deq.virginia.gov

Matthew J. Strickler
Secretary of Natural Resources

David K. Paylor
Director
(804) 698-4000

Thomas A. Faha
Regional Director

February 8, 2019

Mr. Bryan Donnelly
Facility Manager
Covanta Alexandria/Arlington, Inc.
5301 Eisenhower Avenue
Alexandria, Virginia 22304

Location: City of Alexandria
Registration No.: 71895

Dear Mr. Donnelly:

Attached is a permit to operate a solid waste combustor facility in accordance with the provisions of the Commonwealth of Virginia State Air Pollution Control Board Regulations for the Control and Abatement of Air Pollution. This permit is for the purpose of implementing the "reasonably available control technology" (RACT) requirements of 9 VAC 5-40-7400, 9 VAC 5-40-7420 and 9 VAC 5-40-7430 of the Regulations of the Board. Except to the extent that conditions in this permit may be more stringent, this permit does not supersede or replace any other valid permit. Furthermore, this approval to operate shall not relieve Covanta Alexandria/Arlington, Inc. (CAAI) to comply with all other local, state, and federal permit regulations.

This permit contains legally enforceable conditions. Failure to comply may result in a Notice of Violation and civil penalty. Please read all conditions carefully.

At any time in the future, should CAAI plan any modifications (within the context of the new source review program) of the facility covered by this permit, CAAI shall have the right to apply to the Board for a new source review permit and the Board may consent to such modifications provided such modifications will meet all of the new source review permit program regulatory requirements in existence at that time.

Issuance of this permit is a case decision. The Regulations, at 9 VAC 5-170-200, provide that you may request a formal hearing from this case decision by filing a petition with the Board within 30 days after this permit is mailed or delivered to you. Please consult that and other relevant provisions for additional requirements for such requests.

Additionally, as provided by Rule 2A:2 of the Supreme Court of Virginia, you have 30 days from the date you actually received this permit or the date on which it was mailed to you, whichever occurred first, within which to initiate an appeal to court by filing a Notice of Appeal with:

Mr. David K. Paylor, Director
Department of Environmental Quality
P. O. Box 1105
Richmond, VA 23218

In the event that you receive this permit by mail, three days are added to the period in which to file an appeal. Please refer to Part Two A of the Rules of the Supreme Court of Virginia for additional information including filing dates and the required content of the Notice of Appeal.

If you have any questions concerning this permit, please contact the Northern Regional Office at (703) 583-3800.

Sincerely,

Thomas A. Faha
Regional Director

TAF/JBL/HGB/71895-RACT SOP (2-8-2019)

Attachment: Permit

cc: Joseph Walsh, Covanta (electronic file submission)
Riley Burger, EPA Region III
Manager/Inspector, Air Compliance Manager (electronic file submission)

*Commonwealth of Virginia*

*VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY*

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Matthew J. Strickler
Secretary of Natural Resources

David K. Paylor
Director
(804) 698-4000

Thomas A. Faha
Regional Director

## STATIONARY SOURCE PERMIT TO OPERATE

In compliance with the Federal Clean Air Act and the Commonwealth of Virginia Regulations for the Control and Abatement of Air Pollution,

Covanta Alexandria/Arlington, Inc.
5301 Eisenhower Ave.
Alexandria, Virginia 22304
Registration No.: 71895

is authorized to operate

a municipal solid waste combustor facility

located at

5301 Eisenhower Ave.
Alexandria, VA 22304

in accordance with the Conditions of this permit.

Approved on February 8, 2019.

Thomas A. Faha
Regional Director

Permit consists of 9 pages.
Permit Conditions 1 to 26.

## INTRODUCTION/PURPOSE

This permit is, (i) for the purpose of implementing the "reasonably available control technology" (RACT) requirements of 9VAC5-40-7420 of the State Air Pollution Control Board Regulations for the Control and Abatement of Air Pollution ("Regulations"), and (ii) establishes control technology and other requirements for the control of nitrogen oxides ($NO_X$) emissions from Covanta Alexandria/Arlington, Incorporated (CAAI) in the Northern Virginia Ozone Non-Attainment Area and the Ozone Transport Region in Virginia. These RACT requirements shall be the legal and regulatory basis for control of $NO_X$ emissions from this facility.

Words or terms used in this permit shall have meanings as provided in 9VAC5-10-20 of the State Air Pollution Control Board Regulations for the Control and Abatement of Air Pollution. The regulatory reference or authority for each condition is listed in parentheses () after each condition.

The availability of information submitted to the Department of Environmental Quality (DEQ) or the Board will be governed by applicable provisions of the Freedom of Information Act, §§ 2.2-3700 through 2.2-3714 of the Code of Virginia, § 10.1-1314 (addressing information provided to the Board) of the Code of Virginia, and 9VAC5-170-60 of the State Air Pollution Control Board Regulations. Information provided to federal officials is subject to appropriate federal law and regulations governing confidentiality of such information.

## EQUIPMENT LIST

**Equipment List -** Equipment at this facility consists of the following:

| Emission Unit ID | Equipment Description | Rated Capacity | Pollutant(s)* |
|---|---|---|---|
| 001-02 | Keeler/Dorr-Oliver municipal waste combustor with Martin stokers Model # MK 325 (Construction Date Feb. 1988) | 121.8 MMBtu | $NO_X$ |
| 002-02 | Keeler/Dorr-Oliver municipal waste combustor with Martin stokers Model # MK 325 (Construction Date Feb. 1988) | 121.8 MMBtu | $NO_X$ |
| 003-02 | Keeler/Dorr-Oliver municipal waste combustor with Martin stokers Model # MK 325 (Construction Date Feb. 1988) | 121.8 MMBtu | $NO_X$ |

*Pollutant(s) listed for each specified emission unit is only as 9VAC5-40-7420 applies.

## PROCESS REQUIREMENTS

1. **Emission Controls** – Upon completion of the installation and optimization period per Conditions 2 and 3, respectively, nitrogen oxides ($NO_X$) emissions from each municipal waste combustor (MWC) (Ref. 001-02, 002-02, and 003-02) shall be controlled by furnace design, proper operation, good combustion practices, ammonia injection (selective non-catalytic reduction (SNCR)), and the Covanta proprietary low $NO_X$ combustion system (LN™). Until that time, the $NO_X$ emissions shall be controlled by furnace design, proper operation, and ammonia injection (SNCR). The SNCR and LN™ system shall be provided with adequate access for inspection and shall be in operation when each municipal waste combustor (Ref. 001-02, 002-02, and 003-02) is operating.
(9VAC5-80-850 and 9VAC5-40-7420)

2. **Emission Controls** – The permittee shall install the Covanta proprietary low $NO_X$ combustion system (LN™) on the MWCs (Ref. 001-02, 002-02, and 003-02) on a staged basis. The installation shall be completed according to the following schedule;

   a. The LN™ system installed on the first MWC no later than the end of the 4th quarter 2019,

   b. The LN™ system installed on the second MWC no later than the end of the 4th quarter 2020, and

   c. The LN™ system installed on the third MWC no later than the end of the 4th quarter 2021.

   (9VAC5-80-850 and 9VAC5-40-7420)

3. **Emission Controls** – Following the installation of each LN™ systems on the MWCs (Ref. 001-02, 002-02, and 003-02) there shall be no more than a 180-day testing and optimization period, for the respective unit. Completion of the testing/optimization period would mark the start of the revised $NO_X$ emission limits as specified in Condition 4.
(9VAC5-80-850 and 9VAC5-40-7420)

## EMISSION LIMITS

4. **Process Emission Limits** – No later than the testing and optimization period of the LN™ system on each of the MWCs (Ref. 001-02, 002-02, and 003-02), as referenced in Condition 3 above, $NO_X$ emissions from such MWC shall not exceed the following:

   a. Daily Average Nitrogen Oxides
   110 ppmvd @ 7% $O_2$.

   b. Annual Average Nitrogen Oxides
   90 ppmvd @ 7% $O_2$.

   c. The daily average is defined as the hourly rolling average of all hourly average emission concentrations (i.e. 24 hourly averages in a 24-hour period). The 24-hour average calculation should exclude those periods in which no waste was being combusted, when the MWC was not on-line or during periods of startup, shutdown or malfunction.

d. The annual average emissions shall be calculated on a daily basis using the daily average comprising all operating days in the year. Compliance for the annual average period shall be demonstrated daily by averaging the most recently completed daily average with the preceding yearly daily average emissions. The 24-hour average used for the annual average calculation shall begin at 12:00 midnight and continue to the following 12:00 midnight.

Compliance with these emission standards shall be determined by continuous emissions monitors (CEMS) or performance tests.

Compliance with the annual average nitrogen oxide emission limit for each MWC shall begin upon completion of 12 calendar months after the date of this permit, or 12 calendar months following the installation, testing and optimization of the LN™ system on the respective MWC, whichever is later for that unit.
(9VAC5-80-850 and 9VAC5-40-7420)

## MONITORING

5. **CEMS –** A continuous emission monitoring system (CEMS) consisting of a nitrogen oxides ($NO_X$) pollutant concentration monitor, an oxygen ($O_2$) diluent monitor, and an automated data acquisition and handling system meeting the applicable design specifications of 40 CFR Part 60, Appendix B shall be installed to measure and record the emissions of $NO_X$ from each MWC (Ref. 001-02, 002-02, and 003-02) exhaust stack as ppmvd corrected to 7% $O_2$. The CEMS shall be installed, calibrated, maintained, audited and operated in accordance with the requirements of 40 CFR 60.13, 40 CFR 60, Appendices B and F, as applicable, or DEQ approved procedures which are equivalent to the requirements of 40 CFR §60.13 and 40 CFR 60, Appendices B and F, as applicable. Data shall be reduced to one-hour averages and 24-hour rolling averages using procedures approved by the Air Compliance Manager of the DEQ's Northern Regional Office (NRO). The span value for the $NO_X$ monitor shall be 125 percent of the maximum estimated hourly potential $NO_X$ emissions of the MWC unit and the $O_2$ monitor shall be 25 percent $O_2$. Each CEM shall be provided with adequate access for inspection and shall be in operation when the MWC (Ref. 001-02, 002-02, and 003-02) is operating.
(9VAC5-80-850 and 9VAC5-40-7420)

6. **CEMS Quality Control Program –** A CEMS quality control program which meets the requirements of 40 CFR 60.13 and 40 CFR Part 60, Appendix F shall be implemented for all continuous monitoring systems, except that Relative Accuracy Test Audits (RATAs) may be required less frequently if approved by DEQ.
(9VAC5-80-850 and 9VAC5-40-7420)

7. **CEMS Valid Data Collection –** At a minimum, valid $NO_X$ CEMS hourly averages shall be obtained as specified below for 75 percent of the operating hours per day for 90 percent of the operating days per calendar quarter that each MWC unit is combusting MSW.

   a. At least 2 data points per hour shall be used to calculate each 1-hour arithmetic average.

b. Each $NO_X$ 1-hour arithmetic average shall be corrected to 7 percent $O_2$ on an hourly basis using the 1-hour arithmetic average of the $O_2$ CEMS data.

(9VAC5-80-890 and 9VAC5-40-8140 G)

8. **CEMS Data** – All valid $NO_X$ CEMS data shall be used in calculating emission averages even if the minimum CEMS data requirements of Condition 7 are not met.
(9VAC5-80-890 and 9VAC5-40-8140 G)

## TESTING

9. **Emission Testing** – Each municipal waste combustor (Ref. 001-02, 002-02, and 003-02) shall be constructed/modified/installed to allow for emissions testing upon reasonable notice at any time, using appropriate methods. This includes constructing the facility/equipment such that volumetric flow rates and pollutant emission rates are accurately determined by applicable test methods. The permittee shall provide sampling ports when requested at the appropriate locations and safe sampling platforms provided.
(9VAC5-80-850, 9VAC5-80-880, and 9VAC5-40-7490)

## RECORDS

10. **On Site Records** – The permittee shall maintain records of emission data and operating parameters as necessary to demonstrate compliance with this permit. The content and format of such records shall be arranged with the Air Compliance Manager of the DEQ's NRO. These records shall include, but are not limited to;

    a. All 1-hour average $NO_X$ emission concentrations as specified in Conditions 4 and 7.

    b. All 24-hour daily arithmetic average $NO_X$ emission concentrations as specified in Condition 4.

    c. All annual $NO_X$ emission concentrations as specified in Condition 4.

    d. Each calendar date for which the minimum number of hours of any of the $NO_X$ data have not been obtained including reasons for not obtaining sufficient data and a description of corrective actions taken.

    e. The $NO_X$ emission data, or operational data that have been excluded from the calculation of average emission concentrations or parameters, and the reasons for excluding the data.

    f. The permittee shall record the results of daily drift tests, quarterly accuracy determinations, percent operating time, and RATA for $NO_X$ and $O_2$ CEMS, as required under 40 CFR Part 60, Appendix F, Procedure 1.

    g. Scheduled and unscheduled maintenance and operator training.

The records shall be maintained onsite in either paper copy or computer-readable format, unless the Air Compliance Manager of the DEQ's NRO approves an alternative format and shall be available on-site for inspection by DEQ for a period of at least five years.
(9VAC5-80-850, 9VAC5-80-900, and 9VAC5-40-7510)

## NOTIFICATIONS

11. **Emission Controls** – The permittee shall submit to the Regional Air Compliance Manager of DEQ's NRO, a notification of the dates of the commencement and completion of the installation of the LN™ systems on each MWC (Ref. 001-02, 002-02, and 003-02), postmarked no later than 30 days after such dates, or no later than 30 days after the date of this permit, whichever is later.
(9VAC5-80-850, 9VAC5-80-900 and 9VAC5-7510)

12. **Emission Controls** – The permittee shall submit to the Regional Air Compliance Manager of DEQ's NRO, the date of the completion of the testing/optimization period for each MWC, postmarked no later than 30 days after such date, or no later than 30 days after the date of this permit, whichever is later.
(9VAC5-80-850, 9VAC5-80-900 and 9VAC5-7510)

## REPORTING

13. **CEMS Reports** – The permittee shall furnish written reports to the Air Compliance Manager of the DEQ's NRO of excess emissions from any process monitored by a CEMS on a quarterly basis, postmarked no later than the 30th day following the end of the calendar quarter. These reports shall include, but are not limited to the following information:

    a. The magnitude of excess emissions, any conversion factors used in the calculation of excess emissions, and the date and time of commencement and completion of each period of excess emissions;

    b. Specific identification of each period of excess emissions that occurs during startups, shutdowns, and malfunctions of the process, the nature and cause of the malfunction (if known), the corrective action taken or preventative measures adopted;

    c. The date and time identifying each period during which the continuous monitoring system was inoperative except for zero and span checks, other quality assurance (as required in 40 CFR 60, Appendix F) and the nature of the system repairs or adjustments; and

    d. When no excess emissions have occurred or the continuous monitoring systems have not been inoperative, repaired or adjusted, such information shall be stated in that report.

    (9VAC5-80-850 and 9VAC5-40-7420)

14. **NOx Emissions Reporting –** The permittee shall submit semi-annual reports to the Regional Air Compliance Manager of DEQ's NRO for each semi-annual period that emissions exceed the limits of Condition 4. The periods covering each semi-annual period shall be January 1 through June 30 and July 1 through December 31.
(9VAC5-80-900)

15. **NOx Emissions Reporting –** The permittee shall submit the data reports required in Condition 14 no later than March 1 and September 1 of each year following the semiannual period in which the data were collected, unless otherwise approved by the Air Compliance Manager of the DEQ's NRO.
(9VAC5-80-900)

## GENERAL CONDITIONS

16. **Permit Limitations** – Except to the extent that conditions in this permit may be more stringent, this permit does not supersede or replace any other valid permit, regulatory or statutory requirement. Furthermore, this approval to operate shall not relieve Covanta Alexandria/Arlington, Inc. of the responsibility to comply with all other local, state and federal regulations, including permit regulations.
(9VAC5-80-850)

17. **Federal Enforceability** – Once the permit is approved by the U.S. Environmental Protection Agency into the Commonwealth of Virginia State Implementation Plan, the permit is enforceable by EPA and citizens under the federal Clean Air Act.
(9VAC5-80-850)

18. **Permit Revision/Repeal** – The Board may revise (modify, rewrite, change or amend) or repeal this permit with the consent of Covanta Alexandria/Arlington, Inc., for good cause shown by Covanta Alexandria/Arlington, Inc., or on its own motion provided approval of the revision or repeal is accomplished in accordance with Regulations of the Board and the Administrative Process Act (§ 2.2-4000 *et seq.*). Such revision or repeal shall not be effective until the revision or repeal is approved by the U.S. Environmental Protection Agency following the requirements of 40 CFR Part 51 (Requirements for Preparation, Adoption, and Submittal of Implementation Plans).
(9VAC5-80-850)

19. **Failure to Comply –** Failure by Covanta Alexandria/Arlington, Inc. to comply with any of the conditions of this permit shall constitute a violation of a Permit of the Board. Failure to comply may result in a Notice of Violation and civil penalty. Nothing herein shall waive the initiation of appropriate enforcement actions or the issuance of orders as appropriate by the Board as a result of such violations. Nothing herein shall affect appropriate enforcement actions by any other federal, state, or local regulatory authority.
(9VAC5-80-850)

20. **Right of Entry** – The permittee shall allow authorized local, state, and federal representatives, upon the presentation of credentials:

    a. To enter upon the permittee's premises on which the facility is located or in which any records are required to be kept under the terms and conditions of this permit;

    b. To have access to and copy at reasonable times any records required to be kept under the terms and conditions of this permit or the State Air Pollution Control Board Regulations;

    c. To inspect at reasonable times any facility, equipment, or process subject to the terms and conditions of this permit or the State Air Pollution Control Board Regulations; and

    d. To sample or test at reasonable times.

    For purposes of this condition, the time for inspection shall be deemed reasonable during regular business hours or whenever the facility is in operation. Nothing contained herein shall make an inspection time unreasonable during an emergency.
    (9VAC5-170-130 and 9VAC5-80-850)

21. **Notification for Facility or Control Equipment Malfunction** – The permittee shall furnish notification to the Regional Air Compliance Manager of DEQ's NRO of malfunctions of the affected facility or related air pollution control equipment that may cause excess emissions for more than one hour. Such notification shall be made as soon as practicable but no later than four daytime business hours after the malfunction is discovered. The permittee shall provide a written statement giving all pertinent facts, including the estimated duration of the breakdown, within two weeks of discovery of the malfunction. When the condition causing the failure or malfunction has been corrected and the equipment is again in operation, the permittee shall notify the Regional Air Compliance Manager of DEQ's NRO in writing.
    (9VAC5-20-180 C and 9VAC5-80-850)

22. **Violation of Ambient Air Quality Standard** – The permittee shall, upon reasonable request of the DEQ, reduce the level of operation or shut down a facility, as necessary to avoid violating any primary ambient air quality standard and shall not return to normal operation until such time as the ambient air quality standard will not be violated.
    (9VAC5-20-180 I and 9VAC5-80-850)

23. **Maintenance/Operating Procedures** – At all times, including periods of start-up, shutdown, soot blowing, and malfunction, the permittee shall, to the extent practicable, maintain and operate the affected source, including associated air pollution control equipment, in a manner consistent with good air pollution control practices for minimizing emissions.

    The permittee shall take the following measures in order to minimize the duration and frequency of excess emissions, with respect to municipal waste combustor (Ref. 001-02, 002-02, and 003-02) air pollution control equipment, and process equipment which affect such emissions:

    a. Develop a maintenance schedule and maintain records of all scheduled and non-scheduled maintenance.

    b. Maintain an inventory of spare parts.

c. Have available written operating procedures for equipment. These procedures shall be based on the manufacturer's recommendations, as available.

d. Train operators in the proper operation of all such equipment and familiarize the operators with the written operating procedures, prior to their first operation of such equipment. The permittee shall maintain records of the training provided including the names of trainees, the date of training and the nature of the training.

e. Records of maintenance and training shall be maintained on site for a period of five years and shall be made available to DEQ personnel upon request.

(9VAC5-50-20 E and 9VAC5-80-850)

24. **Permit Suspension/Revocation** – This permit may be revoked if the permittee:

a. Knowingly makes material misstatements in the permit application or any amendments to it;

b. Fails to comply with the terms or conditions of this permit;

c. Fails to comply with any emission standards applicable to a permitted emissions unit;

d. Causes emissions from this facility which result in violations of, or interferes with the attainment and maintenance of, any ambient air quality standard;

e. Fails to operate this facility in conformance with any applicable control strategy, including any emission standards or emission limitations, in the State Implementation Plan in effect at the time that an application for this permit is submitted;

f. Fails to comply with the applicable provisions of Articles 6, 8 and 9 of 9VAC5 Chapter 80.

(9VAC5-80-1010)

25. **Change of Ownership** – In the case of a transfer of ownership of a stationary source, the new owner shall abide by any current permit issued to the previous owner. The new owner shall notify the Regional Air Compliance Manager of DEQ's NRO of the change of ownership within 30 days of the transfer.
(9VAC5-80-940)

26. **Permit Copy** – The permittee shall keep a copy of this permit on the premises of the facility to which it applies.
(9VAC5-80-860 D)

*Commonwealth of Virginia*

*VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY*

NORTHERN REGIONAL OFFICE
13901 Crown Court, Woodbridge, Virginia 22193
(703)583-3800 FAX (703) 583-3821
www.deq.virginia.gov

Matthew J. Strickler
Secretary of Natural Resources

David K. Paylor
Director
(804) 698-4000

Thomas A. Faha
Regional Director

February 8, 2019

Mr. Frank Capobianco
Facility Manager
Covanta Fairfax, Inc.
9898 Furnace Road
Lorton, Virginia 22079

Location: Fairfax County
Registration No.: 71920

Dear Mr. Capobianco:

Attached is a permit to operate a solid waste combustor facility in accordance with the provisions of the Commonwealth of Virginia State Air Pollution Control Board Regulations for the Control and Abatement of Air Pollution. This permit is for the purpose of implementing the "reasonably available control technology" (RACT) requirements of 9 VAC 5-40-7400, 9 VAC 5-40-7420 and 9 VAC 5-40-7430 of the Regulations of the Board. Except to the extent that conditions in this permit may be more stringent, this permit does not supersede or replace any other valid permit. Furthermore, this approval to operate shall not relieve Covanta Fairfax, Inc. (CFI) to comply with all other local, state, and federal permit regulations.

This permit contains legally enforceable conditions. Failure to comply may result in a Notice of Violation and civil penalty. Please read all conditions carefully.

At any time in the future, should CFI plan any modifications (within the context of the new source review program) of the facility covered by this permit, CFI shall have the right to apply to the Board for a new source review permit and the Board may consent to such modifications provided such modifications will meet all of the new source review permit program regulatory requirements in existence at that time.

Issuance of this permit is a case decision. The Regulations, at 9 VAC 5-170-200, provide that you may request a formal hearing from this case decision by filing a petition with the Board within 30 days after this permit is mailed or delivered to you. Please consult that and other relevant provisions for additional requirements for such requests.

Additionally, as provided by Rule 2A:2 of the Supreme Court of Virginia, you have 30 days from the date you actually received this permit or the date on which it was mailed to you, whichever occurred first, within which to initiate an appeal to court by filing a Notice of Appeal with:

Mr. David K. Paylor, Director
Department of Environmental Quality
P. O. Box 1105
Richmond, VA 23218

In the event that you receive this permit by mail, three days are added to the period in which to file an appeal. Please refer to Part Two A of the Rules of the Supreme Court of Virginia for additional information including filing dates and the required content of the Notice of Appeal.

If you have any questions concerning this permit, please contact the Northern Regional Office at (703) 583-3800.

Sincerely,

Thomas A. Faha

Thomas A. Faha
Regional Director

TAF/JBL/HGB/71920-RACT SOP (2-8-2019)

Attachment: Permit

cc: Joseph Walsh, Covanta (electronic file submission)
Riley Burger, EPA Region III
Manager/Inspector, Air Compliance Manager (electronic file submission)

*Commonwealth of Virginia*

*VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY*

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Matthew J. Strickler
Secretary of Natural Resources

David K. Paylor
Director
(804) 698-4000

Thomas A. Faha
Regional Director

# STATIONARY SOURCE PERMIT TO OPERATE

In compliance with the Federal Clean Air Act and the Commonwealth of Virginia Regulations for the Control and Abatement of Air Pollution,

Covanta Fairfax, Inc.
9898 Furnace Road
Lorton, Virginia 22079
Registration No.: 71920

is authorized to operate

a municipal solid waste combustor facility

located at

9898 Furnace Road
Lorton, Virginia 22079
(Fairfax County)

in accordance with the Conditions of this permit.

Approved on February 8, 2019.

Thomas A. Faha
Regional Director

Permit consists of 9 pages.
Permit Conditions 1 to 26.

## INTRODUCTION/PURPOSE

This permit is, (i) for the purpose of implementing the "reasonably available control technology" (RACT) requirements of 9VAC5-40-7420 of the State Air Pollution Control Board Regulations for the Control and Abatement of Air Pollution ("Regulations"), and (ii) establishes control technology and other requirements for the control of nitrogen oxides ($NO_X$) emissions from Covanta Fairfax, Inc. (CFI) in the Northern Virginia Ozone Non-Attainment Area and the Ozone Transport Region in Virginia. These RACT requirements shall be the legal and regulatory basis for control of $NO_X$ emissions from this facility. In addition, this facility may be subject to additional applicable requirements not listed in this permit.

Words or terms used in this permit shall have meanings as provided in 9VAC5-10-20 of the Regulations. The regulatory reference or authority for each condition is listed in parentheses () after each condition.

The availability of information submitted to the Department of Environmental Quality (DEQ) or the Board will be governed by applicable provisions of the Freedom of Information Act, §§ 2.2-3700 through 2.2-3714 of the Code of Virginia, § 10.1-1314 (addressing information provided to the Board) of the Code of Virginia, and 9VAC5-170-60 of the State Air Pollution Control Board Regulations. Information provided to federal officials is subject to appropriate federal law and regulations governing confidentiality of such information.

## EQUIPMENT LIST

Equipment at this facility subject to RACT requirements consist of the following:

| Emission Unit ID | Equipment Description | Rated Capacity | Pollutant(s)* |
|---|---|---|---|
| 001-01 | Ogden-Martin MSW Combustor with Martin-Stoker boiler system (Began commercial operation in June 1990) | 343.75 MMBtu/hr (heat input) | $NO_X$ |
| 002-01 | Ogden-Martin MSW Combustor with Martin-Stoker boiler system (Began commercial operation in June 1990) | 343.75 MMBtu/hr (heat input) | $NO_X$ |
| 003-01 | Ogden-Martin MSW Combustor with Martin-Stoker boiler system (Began commercial operation in June 1990) | 343.75 MMBtu/hr (heat input) | $NO_X$ |
| 004-01 | Ogden-Martin MSW Combustor with Martin-Stoker boiler system (Began commercial operation in June 1990) | 343.75 MMBtu/hr (heat input) | $NO_X$ |

* Pollutant(s) listed for each specified emission unit is only as 9VAC5-40-7420 applies.

## PROCESS REQUIREMENTS

1. **Emission Control** – Upon completion of the installation and optimization period per Conditions 2 and 3, respectively, nitrogen oxides ($NO_X$) emissions from each municipal waste combustor (MWC) (Ref. 001-01 through 004-01) shall be controlled by furnace design, proper operation, ammonia injection (selective non-catalytic reduction (SNCR)), and the Covanta proprietary low $NO_X$ combustion system ($LN^{TM}$). Until that time, the $NO_X$ emissions shall be controlled by furnace design, proper operation, and ammonia injection (SNCR). The SNCR and $LN^{TM}$ system shall be provided with adequate access for inspection and shall be in operation when each municipal waste combustor (Ref. 001-01 through 004-01) is operating.
(9VAC5-80-850 and 9VAC5-40-7420)

2. **Emission Controls** – The permittee shall install the Covanta proprietary low $NO_X$ combustion system ($LN^{TM}$) on the MWCs (Ref. 001-01 through 004-01) on a staged basis. The installation shall be completed according to the following schedule;

   a. The $LN^{TM}$ system installed on the first MWC no later than the end of the 2nd quarter 2019,

   b. The $LN^{TM}$ system installed on the second MWC no later than the end of the 4th quarter 2019,

   c. The $LN^{TM}$ system installed on the third MWC no later than the end of the 4th quarter 2020, and

   d. The $LN^{TM}$ system installed on the fourth MWC no later than the end of the 4th quarter 2021.

   (9VAC5-80-850 and 9VAC5-40-7420)

3. **Emission Controls –** Following the installation of each $LN^{TM}$ system on the MWCs, (Ref. 001-01 through 004-01) there shall be no more than a 180-day testing and optimization period for the respective unit. Completion of the testing/optimization period would mark the start of the revised $NO_X$ emission limits as specified in Condition 4.
(9VAC5-80-850 and 9VAC5-40-7420)

## EMISSION LIMITS

4. **Process Emission Limits –** No later than the testing and optimization of the $LN^{TM}$ system on each of the MWCs (Ref. 001-01 through 004-01), as referenced in Condition 3 above, $NO_X$ emissions from such MWC shall not exceed the following:

   a. Daily Average Nitrogen Oxides
   110 ppmvd @ 7% $O_2$.

   b. Annual Average Nitrogen Oxides
   90 ppmvd @ 7% $O_2$.

   c. The daily average is defined as the hourly rolling average of all hourly average emission concentrations (i.e. 24 hourly averages in a 24-hour period). The 24-hour average calculation should exclude those periods in which no waste was being combusted, when the MWC was not on-line or during periods of startup, shutdown or malfunction.

d. The annual average emissions shall be calculated on a daily basis using the daily average comprising all operating days in the year. Compliance for the annual average period shall be demonstrated daily by averaging the most recently completed daily average with the preceding yearly daily average emissions. The 24-hour average used for the annual average calculation shall begin at 12:00 midnight and continue to the following 12:00 midnight.

Compliance with these emission standards shall be determined by continuous emissions monitors (CEMS) or performance tests.

Compliance with the annual average nitrogen oxide emission limit for each MWC shall begin upon completion of 12 calendar months after the date of this permit, or 12 calendar months following the installation, testing and optimization of the LN™ system on the respective MWC, whichever is later for that unit.
(9VAC5-80-850 and 9VAC5-40-7420)

## MONITORING

5. **CEMS** – A continuous emission monitoring system (CEMS) consisting of a nitrogen oxides ($NO_X$) pollutant concentration monitor, an oxygen ($O_2$) diluent monitor, and an automated data acquisition and handling system meeting the applicable design specifications of 40 CFR Part 60, Appendix B shall be installed to measure and record the emissions of $NO_X$ from each MWC (Ref. 001-01 through 004-01) exhaust stack as ppmvd, corrected to 7% $O_2$. The CEMS shall be installed, calibrated, maintained, audited and operated in accordance with the requirements of 40 CFR 60.13, 40 CFR 60, Appendices B and F, as applicable, or DEQ approved procedures which are equivalent to the requirements of 40 CFR §60.13 and 40 CFR 60, Appendices B and F, as applicable. Data shall be reduced to one-hour averages and 24-hour rolling averages using procedures approved by the Air Compliance Manager of the DEQ's Northern Regional Office (NRO). The span value for the $NO_X$ monitor shall be 125 percent of the maximum estimated hourly potential $NO_X$ emissions of the MWC unit and the $O_2$ monitor shall be 25 percent $O_2$. Each CEM shall be provided with adequate access for inspection and shall be in operation when the MWC (Ref. 001-01 through 004-01) is operating.
(9VAC5-80-850 and 9VAC5-40-7420)

6. **CEMS Quality Control Program** – A CEMS quality control program which meets the requirements of 40 CFR §60.13 and 40 CFR Part 60, Appendix F shall be implemented for all continuous monitoring systems, except that Relative Accuracy Test Audits (RATAs) may be required less frequently if approved by DEQ.
(9VAC5-80-850 and 9VAC5-40-7420)

7. **CEMS Valid Data Collection** – At a minimum, valid $NO_X$ CEMS hourly averages shall be obtained as specified below for 75 percent of the operating hours per day for 90 percent of the operating days per calendar quarter that each MWC unit is combusting MSW.

   a. At least 2 data points per hour shall be used to calculate each 1-hour arithmetic average.

b. Each $NO_X$ 1-hour arithmetic average shall be corrected to 7 percent $O_2$ on an hourly basis using the 1-hour arithmetic average of the $O_2$ CEMS data.

(9 VAC 5-80-890 and 9VAC5-40-8140 G)

8. **CEMS Data** – All valid $NO_X$ CEMS data shall be used in calculating emission averages even if the minimum CEMS data requirements of Condition 7 are not met.
(9VAC5-80-890 and 9VAC5-40-8140 G)

## TESTING

9. **Emission Testing** – Each municipal waste combustor (Ref. 001-01 through 004-01) shall be constructed/modified/installed to allow for emissions testing upon reasonable notice at any time, using appropriate methods. This includes constructing the facility/equipment such that volumetric flow rates and pollutant emission rates are accurately determined by applicable test methods. The permittee shall provide sampling ports when requested at the appropriate locations and safe sampling platforms provided.
(9VAC5-80-850, 9VAC5-80-880, and 9VAC5-40-7490)

## RECORDS

10. **On Site Records** – The permittee shall maintain records of emission data and operating parameters as necessary to demonstrate compliance with this permit. The content and format of such records shall be arranged with the Air Compliance Manager of the DEQ's NRO. These records shall include, but are not limited to;

   a. All 1-hour average $NO_X$ emission concentrations as specified in Conditions 4 and 7.

   b. All 24-hour daily arithmetic average $NO_X$ emission concentrations as specified in Condition 4.

   c. All annual $NO_X$ emission concentrations as specified in Condition 4.

   d. Each calendar date for which the minimum number of hours of any of the $NO_X$ data have not been obtained including reasons for not obtaining sufficient data and a description of corrective actions taken.

   e. The $NO_X$ emission data, or operational data that have been excluded from the calculation of average emission concentrations or parameters, and the reasons for excluding the data.

   f. The permittee shall record the results of daily drift tests, quarterly accuracy determinations, percent operating time, and RATA for $NO_X$ and $O_2$ CEMS, as applicable, as required under 40 CFR Part 60, Appendix F, Procedure 1.

   g. Scheduled and unscheduled maintenance and operator training.

The records shall be maintained onsite in either paper copy or computer-readable format, unless the Air Compliance Manager of the DEQ's NRO approves an alternative format and shall be available on-site for inspection by DEQ for a period of at least five years.
(9VAC5-80-850, 9VAC5-80-900, and 9VAC5-40-7510)

## NOTIFICATIONS

11. **Emission Controls** – The permittee shall submit to the Regional Air Compliance Manager of DEQ's NRO, a notification of the dates of the commencement and completion of the installation of the LN™ systems on each MWC (Ref. 001-01 through 004-01), postmarked no later than 30 days after such dates, or no later than 30 days after the date of this permit, whichever is later.
(9VAC5-80-850, 9VAC5-80-900 and 9VAC5-7510)

12. **Emission Controls** – The permittee shall submit to the Regional Air Compliance Manager of DEQ's NRO the date of the completion of the testing/optimization period for each MWC, postmarked no later than 30 days after such date, or no later than 30 days after the date of this permit, whichever is later.
(9VAC5-80-850, 9VAC5-80-900 and 9VAC5-7510)

## REPORTING

13. **CEMS Reports** – The permittee shall furnish written reports to the Air Compliance Manager of the DEQ's NRO of excess emissions from any process monitored by a CEMS on a quarterly basis, postmarked no later than the 30th day following the end of the calendar quarter. These reports shall include, but are not limited to the following information:

    a. The magnitude of excess emissions, any conversion factors used in the calculation of excess emissions, and the date and time of commencement and completion of each period of excess emissions;

    b. Specific identification of each period of excess emissions that occurs during startups, shutdowns, and malfunctions of the process, the nature and cause of the malfunction (if known), the corrective action taken or preventative measures adopted;

    c. The date and time identifying each period during which the continuous monitoring system was inoperative except for zero and span checks, other quality assurance (as required in 40 CFR 60, Appendix F) and the nature of the system repairs or adjustments; and

    d. When no excess emissions have occurred or the continuous monitoring systems have not been inoperative, repaired or adjusted, such information shall be stated in that report.

    (9VAC5-80-850 and 9VAC5-40-7420)

14. **NOx Emissions Reporting –** The permittee shall submit semi-annual reports to the Regional Air Compliance Manager of DEQ's NRO for each semi-annual period that emissions exceed the limits of Condition 4. The periods covering each semi-annual period shall be January 1 through June 30 and July 1 through December 31.
(9VAC5-80-900)

15. **NOx Emissions Reporting** – The permittee shall submit the data reports required in Condition 14 no later than March 1 and September 1 of each year following the semiannual period in which the data were collected, unless otherwise approved by the Air Compliance Manager of the DEQ's NRO.
(9VAC5-80-900)

## GENERAL CONDITIONS

16. **Permit Limitations –** Except to the extent that conditions in this permit may be more stringent, this permit does not supersede or replace any other valid permit, regulatory or statutory requirement. Furthermore, this approval to operate shall not relieve Covanta Fairfax, Inc. (CFI) of the responsibility to comply with all other local, state and federal regulations, including permit regulations.
(9VAC5-80-850)

17. **Federal Enforceability** – Once the permit is approved by the U.S. Environmental Protection Agency into the Commonwealth of Virginia State Implementation Plan, the permit is enforceable by EPA and citizens under the federal Clean Air Act.
(9VAC5-80-850)

18. **Permit Revision/Repeal** – The Board may revise (modify, rewrite, change or amend) or repeal this permit with the consent of CFI, for good cause shown by CFI, or on its own motion provided approval of the revision or repeal is accomplished in accordance with Regulations of the Board and the Administrative Process Act (§ 2.2-4000 *et seq.*). Such revision or repeal shall not be effective until the revision or repeal is approved by the U.S. Environmental Protection Agency following the requirements of 40 CFR Part 51 (Requirements for Preparation, Adoption, and Submittal of Implementation Plans).
(9VAC5-80-850)

19. **Failure to Comply –** Failure by CFI to comply with any of the conditions of this permit shall constitute a violation of a Permit of the Board. Failure to comply may result in a Notice of Violation and civil penalty. Nothing herein shall waive the initiation of appropriate enforcement actions or the issuance of orders as appropriate by the Board as a result of such violations. Nothing herein shall affect appropriate enforcement actions by any other federal, state, or local regulatory authority.
(9VAC5-80-850)

20. **Right of Entry –** The permittee shall allow authorized local, state, and federal representatives, upon the presentation of credentials:

    a. To enter upon the permittee's premises on which the facility is located or in which any records are required to be kept under the terms and conditions of this permit;

b. To have access to and copy at reasonable times any records required to be kept under the terms and conditions of this permit or the State Air Pollution Control Board Regulations;

c. To inspect at reasonable times any facility, equipment, or process subject to the terms and conditions of this permit or the State Air Pollution Control Board Regulations; and

d. To sample or test at reasonable times.

For purposes of this condition, the time for inspection shall be deemed reasonable during regular business hours or whenever the facility is in operation. Nothing contained herein shall make an inspection time unreasonable during an emergency.
(9VAC5-170-130 and 9VAC5-80-850)

21. **Notification for Facility or Control Equipment Malfunction –** The permittee shall furnish notification to the Regional Air Compliance Manager of DEQ's NRO of malfunctions of the affected facility or related air pollution control equipment that may cause excess emissions for more than one hour. Such notification shall be made as soon as practicable but no later than four daytime business hours after the malfunction is discovered. The permittee shall provide a written statement giving all pertinent facts, including the estimated duration of the breakdown, within two weeks of discovery of the malfunction. When the condition causing the failure or malfunction has been corrected and the equipment is again in operation, the permittee shall notify the Regional Air Compliance Manager of DEQ's NRO in writing.
(9VAC5-20-180 C and 9VAC5-80-850)

22. **Violation of Ambient Air Quality Standard –** The permittee shall, upon reasonable request of the DEQ, reduce the level of operation or shut down a facility, as necessary to avoid violating any primary ambient air quality standard and shall not return to normal operation until such time as the ambient air quality standard will not be violated.
(9VAC5-20-180 I and 9VAC5-80-850)

23. **Maintenance/Operating Procedures –** At all times, including periods of start-up, shutdown, soot blowing, and malfunction, the permittee shall, to the extent practicable, maintain and operate the affected source, including associated air pollution control equipment, in a manner consistent with good air pollution control practices for minimizing emissions.

The permittee shall take the following measures in order to minimize the duration and frequency of excess emissions, with respect to each municipal waste combustor (Ref. 001-01 through 004-01) air pollution control equipment, and process equipment which affect such emissions:

a. Develop a maintenance schedule and maintain records of all scheduled and non-scheduled maintenance.

b. Maintain an inventory of spare parts.

c. Have available written operating procedures for equipment. These procedures shall be based on the manufacturer's recommendations, as available.

d. Train operators in the proper operation of all such equipment and familiarize the operators with the written operating procedures, prior to their first operation of such equipment. The permittee shall maintain records of the training provided including the names of trainees, the date of training and the nature of the training.

e. Records of maintenance and training shall be maintained on site for a period of five years and shall be made available to DEQ personnel upon request.

(9VAC5-50-20 E and 9VAC5-80-850)

24. **Permit Suspension/Revocation** – This permit may be revoked if the permittee:

    a. Knowingly makes material misstatements in the permit application or any amendments to it;

    b. Fails to comply with the terms or conditions of this permit;

    c. Fails to comply with any emission standards applicable to a permitted emissions unit;

    d. Causes emissions from this facility which result in violations of, or interferes with the attainment and maintenance of, any ambient air quality standard;

    e. Fails to operate this facility in conformance with any applicable control strategy, including any emission standards or emission limitations, in the State Implementation Plan in effect at the time that an application for this permit is submitted;

    f. Fails to comply with the applicable provisions of Articles 6, 8 and 9 of 9VAC5 Chapter 80.

    (9VAC5-80-1010)

25. **Change of Ownership** – In the case of a transfer of ownership of a stationary source, the new owner shall abide by any current permit issued to the previous owner. The new owner shall notify the Regional Air Compliance Manager of DEQ's NRO of the change of ownership within 30 days of the transfer.
    (9VAC5-80-940)

26. **Permit Copy** – The permittee shall keep a copy of this permit on the premises of the facility to which it applies.
    (9VAC5-80-860 D)

# Attachment B

Excerpt from Ozone Transport Commission ("OTC") Response to Comments – Municipal Waste Combustor Stakeholder Process

# Comments from Ozone Transport Commission (OTC) Municipal Waste Combustor (MWC) Stakeholders and OTC Responses

1. **Joe Walsh (Covanta):** Is there an email to send comments to?

**OTC response: ccooper@nescaum.org**

2. **MHB:** Has OTC or OTC member states considered whether recent pricing for urea affects the results of the study?

**OTC response: The workgroup recognizes that the cost of consumables, including reagents, and material and labor related to NOx control has increased since the performance of the engineering studies that the workgroup referenced in developing its cost effectiveness estimates. The cost effectiveness estimates were developed with the goal of using those values, or range of values, to compare with pollution control RACT threshold values sometimes utilized by the states in judging the cost effectiveness of a proposed control strategy. Therefor the existing estimates allow a more even comparison to cost effectiveness thresholds that have been in place for some time to allow the reader to better judge the relative value of cost effectiveness estimates cited in the report. It is anticipated that unit specific RACT analysis performed in accordance with the applicable state's RACT procedure would be performed using the latest cost information to compare with the state's RACT threshold.**

3. **George Drew (Covanta):** Has the MWC workgroup looked at other Covanta designs, such as Martin stoker or RDF combustion? If not, can that be reviewed as part of this project?

**OTC response: The workgroup reviewed publicly available data for all MWC units located in the OTR. The bulk of the report concentrated on MWCs where there have been recent engineering studies or completed NOx reduction projects to assess commercially available NOx reduction technologies, the applicability and effectiveness of those reduction technologies, and the estimated cost effectiveness of those technologies. Additional analysis to address additional differences in MWC designs would require more unit specific NOx reduction project information than the workgroup was able to locate. The workgroup identified a number of NOx reduction technologies that are commercially available and applicable to many MWC designs. The report contains a brief discussion for a number of generic MWC designs and, where applicable, provides some information about the applicability of various NOx control for those generic MWC designs.**

4. **George Drew (Covanta)**: is this recommendation based on RACT criteria?

**OTC response: The goal of the workgroup was to identify commercially available, technically feasible NOx reduction technologies applicable to large MWCs. Where engineering studies were available, cost effectiveness values were estimated. Presumptive NOx RACT rates were proposed, coinciding with the selected NOx reduction technologies and the associated cost effectiveness. It is anticipated that the proposed presumptive RACT rates could be utilized by a state for use in conducting unit**

**16. Michael Van Brunt (Covanta):**

Thank you for the opportunity to participate in the OTC's December 14, 2021 stakeholder meeting regarding the Stationary and Area Sources Committee Municipal Waste Combustor (MWC) Workgroup Report, dated June 2021 (the "Report"). The Report summarized research and recommendations related to NOx emissions from MWCs within the OTC region. Specifically, the Report identified existing NOx reduction efforts undertaken at various MWCs, either voluntarily or in response to regulatory rule adoptions, with a specific focus on facilities located in Maryland and Virginia. The Report concludes, in part, that Covanta's Low NOx (LN™) proprietary technology can be deployed at our MWCs to achieve significant NOx emission reductions. As discussed further below, Covanta owns and/or operates a variety of combustion technologies that require case-by-case evaluation of the effectiveness and feasibility of LN™ and other NOx emission reduction technologies.

The following are our comments on the Report.

***The limitations of Covanta Low NOx (LN™) should be more fully characterized in the Report.***

Covanta's proprietary LN™ technology involves the staging of combustion air within the combustion chamber, along with the use of selective non-catalytic reduction (SNCR) to achieve lower NOx emissions, as described in the Report. Specifically, the Report addresses Covanta's LN™ technology as implemented at the Covanta Fairfax (Lorton, VA), Covanta Alexandria (Alexandria, VA) and Montgomery County (Dickerson, MD) MWCs, along with references to the Hillsborough FL, Bristol, CT and Essex County, NJ MWCs. Based on public sources of information related to these facilities, the Report concludes that "information indicates that Covanta run facilities across a wide range of sizes and manufacturers, can be retrofitted with the proprietary Covanta LN™ technology and achieve significant [NOx] reductions".

Covanta owns and/or operates MWC's located both within and outside of the OTC region. Our MWCs include multiple technology types as outlined in Tables 1 and 2 in the attached Appendix A. LN™ is currently operated on only two of those technologies.

Some of the remaining technologies may be amenable to LN™; however, the efficacy of LN™ has not yet been demonstrated in practice. Differences related to combustion air flows, flue gas velocities, length and width of the combustion grate and furnace, heat transfer potential, number and location of auxiliary burners, etc. can have a significant impact on both the initial formation of NOx in the furnace, as well as the effectiveness of combustion air staging in reducing that formation. For these technologies, we believe that it is premature to recommend a numerical limit that has been demonstrated through LN™.

Other MWC technologies, including rotary combustors in place at two of our facilities in Pennsylvania, cannot be retrofitted with our current LN™ technology due to their unique equipment configuration. In addition, the Aireal grate technology deployed at the Susquehanna Resource Management Complex (Harrisburg, PA) has insufficient waste agitation and underfire air (combustion air below the grate) distribution to accommodate a LN™ retrofit. Our Resource Derived Fuel (RDF) units utilize air to disperse the waste onto the combustion grate which can cause temperature differentials within the combustion zone.

Still other MWC technologies already have combustion conditions roughly analogous to those developed under LN™ conditions, yet do not currently meet the limits the OTC is considering for recommendation. We believe that there may be opportunities to reduce NOx emissions from these technologies following different approaches. As such, we have already committed to a voluntary effort with the PADEP to conduct an SNCR trial on one of the rotary combustors at our Delaware Valley facility in Chester, PA; however, we do not yet know the NOx concentrations we will be able to achieve in practice.

Given that LN$^{TM}$ has only been proven at two of the MWC technologies we operate, we recommend that the OTC clarify the potential application of LN$^{TM}$ as follows:

“Information indicates that the proprietary Covanta LN$^{TM}$ technology has achieved significant NOx reductions across a wide range of sizes for certain grate and boiler technology combinations. NOx reductions may be possible at other technologies or through other means but have not yet been demonstrated.”

**OTC Response: The goal of the OTC’s MWC workgroup activity was to evaluate existing publicly available information for the purpose of developing recommended presumptive RACT limits for existing MWCs located in the OTR. These presumptive RACT limits were to represent the emission control capability of commercially available control technologies that could be retrofit on the existing MWCs in a cost-effective manner. The report identified a number of commercially available control technologies, both singly and in conjunction with other control technologies, that that have the potential to achieve NOx emission reductions in retrofit installation for a variety of MWC sizes and configurations. It was not the intention of the workgroup to indicate that any individual technology example was capable of meeting the presumptive RACT limits on any given unit, but rather that its effectiveness had been demonstrated in industry.**

**The report includes a brief discussion of the generic types of MWCs found in the OTR. The report also includes discussion of available and applicable NOx control technologies that may be considered for retrofit application on those generic MWCs. The more detailed discussion of the Covanta trademark LN technology was very helpful to the workgroup and showcases the level of work and commitment by Covanta to control NOx emissions from its MWCs.**

**The presumptive RACT values proposed in the report represent NOx control capabilities that have been demonstrated to be technically feasible and within a range of cost effectiveness values utilized by some states in their NOx RACT evaluations. The workgroup feels that the proposed presumptive RACT values are technologically and economically feasible across a wide range of existing MWCs and may be helpful to states in their conduct of NOx RACT evaluations for individual MWC units located in their state.**

**While the workgroup does not feel that the existing language in the report implies that the Covanta trademark LN technology is the only retrofit NOx control technology available to any Covanta MWC, or that its control capabilities would be the same for all individual units, the workgroup does not have any issue with adding text that indicates the Covanta trademark LN is not universally applicable to all Covanta MWCs.**

As indicated during the stakeholder meeting in December 2021, the OTC conducted a RACT-type analysis of the various MWC’s operating in the region. By rule, RACT analyses are to consider both technical feasibility and cost for each alternative evaluated. Specifically, the Report excerpts cost data from the NOx RACT analysis prepared for the Covanta Fairfax MWC and submitted to the Virginia

<u>Attachment C</u>

Babcock Power Waste to Energy NOx Feasibility Study Prepared for Wheelabrator Technologies Baltimore Waste to Energy, Baltimore, Maryland, BPE Project No. 100825 (February 20, 2020)

Babcock Power Environmental
a Babcock Power Inc. company

# WASTE TO ENERGY $NO_X$ FEASIBILITY STUDY

PREPARED FOR:

WHEELABRATOR TECHNOLOGIES
BALTIMORE WASTE TO ENERGY FACILITY
BALTIMORE, MARYLAND

BPE PROJECT NO. : 100825

BPE DOCUMENT NO.:
100825-0908400100
FINAL REVISION

FEBRUARY 20, 2020

## TABLE OF CONTENTS

# 1.0 INTRODUCTION

The purpose of this study is to provide a feasibility analysis for additional control of $NO_X$ emissions from the Wheelabrator Baltimore Waste-to-Energy (WTE) Facility. The three (3) Municipal Waste Combustors (MWCs) at Wheelabrator Baltimore converts a maximum of 2,250 tons per day (750 tpd per MWC) of post-recycled municipal solid waste from Baltimore area homes and businesses as a local, sustainable fuel to generate as much as 64.5 gross (52 net) MW of electricity for sale to the local utility in addition to supplying steam to downtown Baltimore city businesses.

In this study, Babcock Power Environmental (BPE) details existing facility operations and performance and provides an overview of currently available technologies to enhance current $NO_X$ emission levels. Each technology is then analyzed for technical feasibility. Capital and operating costs, along with an estimated timeline for installation are also included for those technologies deemed technically feasible.

BPE is not a subject matter expert on Selective Non-Catalytic Reduction (SNCR) systems. BPE therefore contracted with Fuel Tech, Inc. as a part of this study to provide a more comprehensive analysis of SNCR and Advanced SNCR (ASNCR) system capabilities. Discussions in this study on SNCR and ASNCR technology and performance are the work of Fuel Tech, Inc.

This $NO_X$ feasibility study addresses the $NO_X$ control technology processes, predicted performance, and plant arrangement. Detailed engineering, design, and construction of essential project parameters such as electrical work, civil work (foundations, pilings, site preparation), and balance of plant for integrating the various $NO_X$ control technologies into existing plant have not been technically evaluated as a part of this feasibility study. However, costs for these have been considered per industry standards in the estimation of capital costs [1].

# 2.0 EXISTING FACILITY OPERATIONS

## *2.1 Boiler Design*

Wheelabrator Baltimore WTE Facility consists of three (3) MWCs with Sterling power boilers supplied by the Babcock & Wilcox Company. The facility has been operating since 1983. Each MWC boiler was designed to process 750 tons per Day (TPD) of municipal solid waste (MSW), having a high heating value of 5,200 Btu/lbm, and generates 193,600 lbm/hr of superheated steam at 850 psia and 830°F. An economizer heats the feedwater temperature from 290°F to 500°F. The stoker on this MWC is a Von Roll reciprocating design. The height, width, and depth of the boiler's furnace are 88 feet (measured in the middle of the furnace from top of stoker to the roof tubes), 26.5 feet, and 19 feet 11 inches respectively. The bullnose on the rear wall at the middle elevation of the furnace redirects flue gas upward toward the front of the furnace and through the waterwall platens. Each furnace is equipped with twelve (12) waterwall platens located across the width of the furnace front wall. The waterwall platens provide additional surface area for heat absorption to moderate gas temperature entering the superheater to minimize high temperature corrosion of the superheater tubes. The flue gas flows across the superheater tubes in the direction east to west. It then flows down across and over the vertical boiler bank tubes and then across and up through the economizer's vertical tubes.

The flue gas flow is pushed towards the rear wall, reducing residence time and limiting chemical coverage for SNCR urea injection.

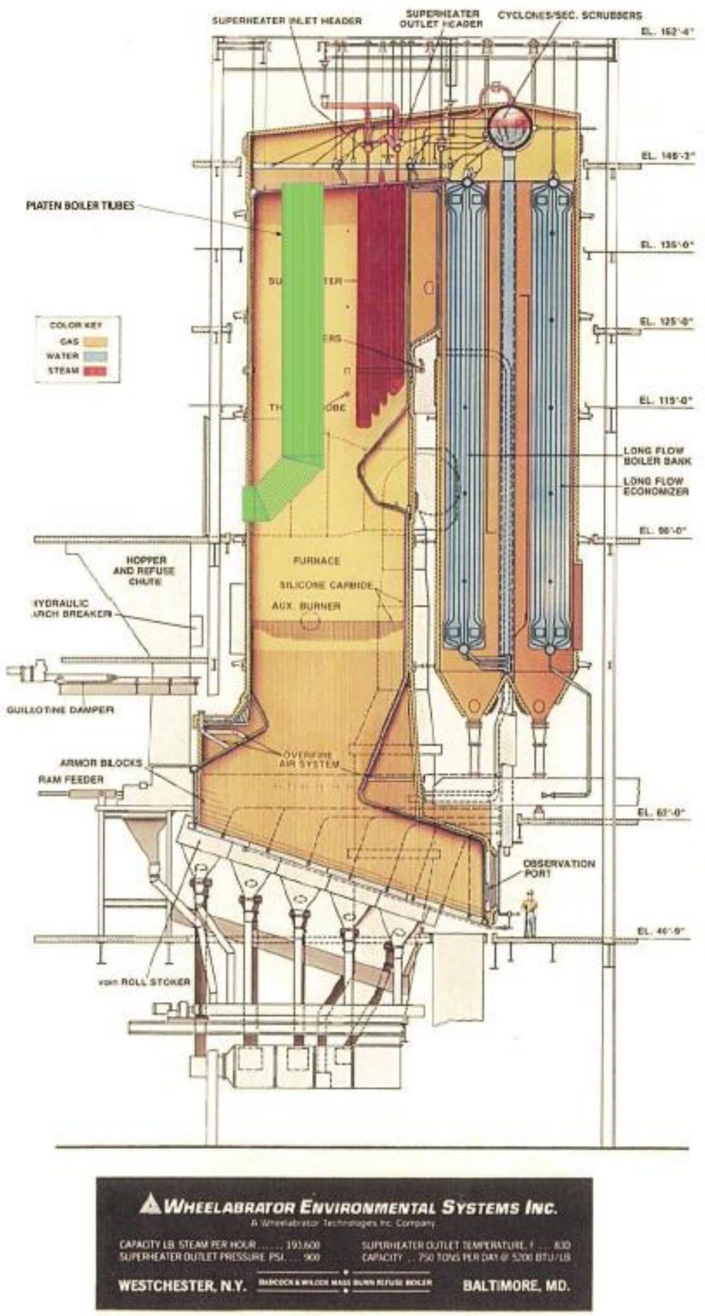



**Figure 1: Wheelabrator Baltimore Municipal Waste Combustor**

## *2.2 Existing $NO_X$ Control Technologies & Emissions Performance*

At the Baltimore facility, each of the three (3) MWCs is currently equipped with a Selective Non-Catalytic Reduction (SNCR) system supplied by Fuel Tech. Section 3.1 provides a high-level description of the SNCR process, along with some critical SNCR process parameters.

The existing SNCR systems have been optimized to meet the $NO_X$ Reasonably Available Control Technology (RACT) limit of 150 ppmvd at 7% $O_2$ (average), which became effective on May 1, 2019. The existing systems will also be able to meet the 30-day rolling average limit of 145 ppmvd 7% $O_2$ that will become effective on May 1, 2020. The 150 ppmvd limit has been met to date without evidence of excess ammonia that could potentially cause a visible ammonium chloride plume.

The SNCR system has injectors located at Elevation 82'-3" with one (1) injector per corner, one (1) injector per side wall, and two (2) injectors on the rear wall for a total of eight (8) in each MWC furnace. The injectors are equipped with variable spray angle tips. Although the injectors are fixed, changing the point of chemical release by changing injector tip angle and adjusting atomizing air and/or dilution water flow provides additional flexibility to optimize system further. Specifically, if the temperature is higher than anticipated, larger droplets will delay the chemical evaporation and the reaction will take place at a lower temperature environment thus optimizing the performance of the SNCR system.

# 3.0 POTENTIAL $NO_X$ CONTROL TECHNOLOGIES

BPE and Fuel Tech have identified several potential $NO_X$ control technologies that were evaluated as part of this feasibility analysis. The following section outlines the identified technologies in general terms. The feasibility of those technologies as they relate to the Baltimore facility is detailed in Section 4.0.

## *3.1 Existing SNCR*

As discussed in Section 2.2, each of the three (3) units is currently equipped with a Selective Non-Catalytic Reduction (SNCR) system. Urea (a nitrogen-based reducing agent, or reagent) is injected into the post-combustion flue gas. The SNCR process occurs within the furnace, which acts as the reaction chamber. The reagent is injected via nozzles mounted on the walls of the furnace. The heat of the boiler provides energy for the reaction, which reduces the $NO_X$ molecules into molecular nitrogen ($N_2$) and water vapor ($H_2O$). Note that the $NO_X$ is represented as NO since it is the predominant form of $NO_X$ within the boiler. The temperature window for effective SNCR performance is a function of the baseline $NO_X$ but typically ranges between 1600°F and 2000°F.

The successful implementation of the urea based SNCR technology is predicated on the ability to introduce urea as a liquid spray (a mixture of 50% urea solution and dilution water as carrier) into the boiler using specialized injectors. These spray droplets travel through the furnace until they evaporate with $NO_x$ reduction reactions start only after the chemical has been released. The SNCR reactions are all gas phase and the term "reaction temperature" is used interchangeably with temperature at the point of chemical release. This reflects the location where the chemical starts to react. Residence time refers to the time available for reaction after chemical release while the reducing agent is still within the appropriate chemical and thermal environment.

Figure 2 below illustrates the mechanics of urea injection into a boiler.

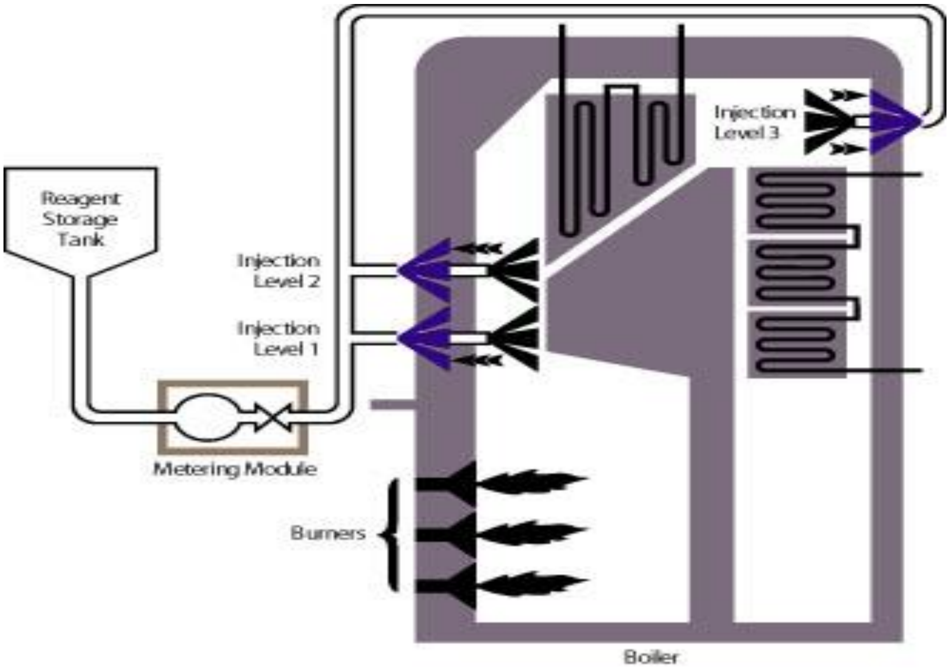



**Figure 2: SNCR System with Multiple Levels of Injection**

There are close to 100 chemical reactions involving more than 30 species in the SNCR mechanism that utilizes urea as a reducing agent. The overall reaction, however, can be expressed as follows:

$$CON_2H_4 + 2NO + \frac{1}{2} O_2 \rightarrow CO_2 + 2H_2O + 2N_2 \quad (1)$$

Chain radical species such as O, H, and OH are required for the reactions to proceed. While $NO_X$ reduction and formation reactions take place continuously, the temperature and the concentration of the OH radicals are the determining factors as to which reaction path will dominate. The activation, reduction and formation reactions are listed below:

### 3.1.1 Urea Breakdown and Activation Reactions

Urea in itself does not react with $NO_X$, but under high temperature conditions generates $NH_2$ and NCO. These are the species that react with $NO_X$.

$$CON_2H_4 \rightarrow NH_3 + HNCO \quad (2)$$

$$NH_3 + OH \rightarrow NH_2 + H_2O \quad (3)$$

$$HNCO + OH \rightarrow NCO + H_2O \quad (4)$$

### 3.1.2 $NO_X$ Reduction Reactions

$NH_2$ and NCO react with $NO_x$, stripping off an oxygen atom and reducing it to molecular nitrogen.

$$NH_2 + NO \rightarrow NNH + OH \rightarrow N_2 + H_2O \quad (5)$$

$$NCO + NO \rightarrow N_2O + CO \rightarrow N_2 + CO_2 \quad (6)$$

### 3.1.3 $NO_X$ Formation Reactions

$NH_2$ and NCO react with hydroxyl radicals and generate $NO_X$.

$$NH_2 + 3OH \rightarrow NO + 2H_2O + H \quad (7)$$

$$NCO + OH \rightarrow NO + CO + H \quad (8)$$

Although application specific, typically at high temperatures above approximately 2050°F), the $NO_x$ formation reactions dominate while at lower temperatures the $NO_X$ reduction reactions become predominant. At temperatures below 1500°F, the chemical kinetics slow down considerably, and the activation reactions proceed at a very slow rate. Not only is $NO_X$ not reduced, but the $NH_3$ is not converted to $NH_2$ quickly enough resulting in high ammonia slip as a byproduct of the injection. Figure 3 below shows a generic depiction of $NO_X$ reduction and ammonia slip vs. temperature.

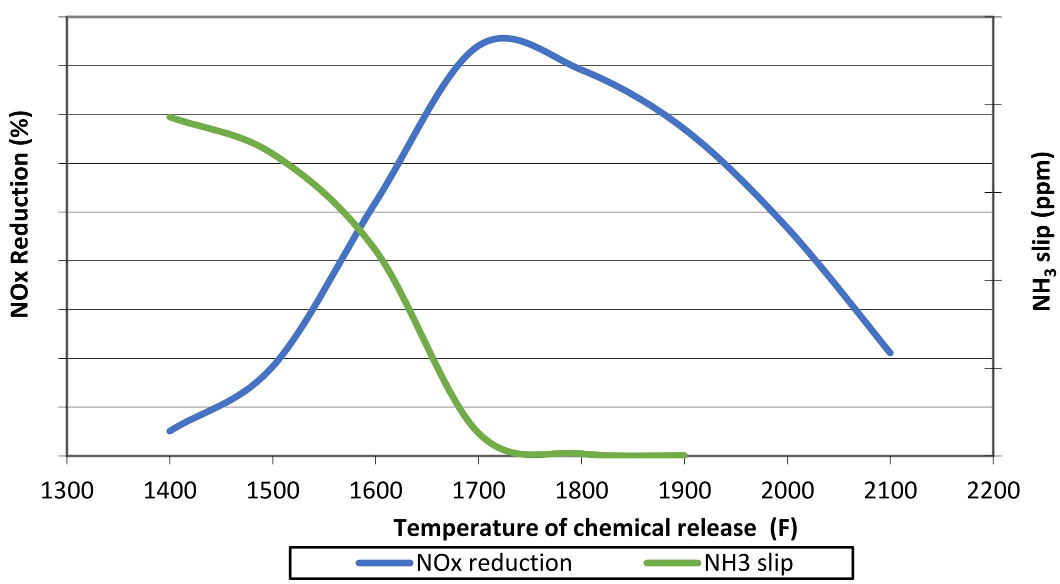



**Figure 3: $NO_X$ Reduction and Ammonia Slip vs. Temperature**

### *3.2 Advanced SNCR (ASNCR)*

An Advanced-SNCR (ASNCR) system utilizes acoustic or laser-based means of producing near real-time maps of furnace temperature conditions that are then used to control the location and manner of injection for $NO_X$ control. In some cases, the temperature monitoring is the primary control signal used to control urea and/or dilution water flow. In other cases, the temperature monitoring is used to select injectors within an injection zone for special operations.

Typically, urea based SNCR systems have logic designed to control operations based on unit load, CEMS $NO_X$, upper furnace temperature, and ammonia slip data. The Advanced SNCR system provides additional flexibility, utilizing Computational Fluid Dynamics (CFD) modeling and Chemical Kinetic Modeling (CKM) technology in concert with near real-time furnace temperature maps to modify individual injection selection or urea flow rates.

SNCR "performance" can be measured in many ways, and all are important to varying degrees. The achievable $NO_X$ reduction and ammonia slip are the foremost measures of performance. The chemical utilization is also critical to the operating cost of the system, as are the amount of dilution water and injection air used. Finally, the ability of the system to operate dynamically and effectively over a wide load range is also significant.

In simplified terms, the temperature profile can be mapped over an existing control scheme to activate only the injectors that are expected to provide the best performance. This can be managed in the short-term by responding to apparent conditions in the furnace. A schematic illustrating temperature-based injector selection is shown in Figure 4. It has also been possible to measure variations in the furnace and develop algorithms to predict expected conditions in the near future. These algorithms include predictions of furnace gas concentrations and temperature changes that can be anticipated to improve chemical use and minimize balance of plant impacts.

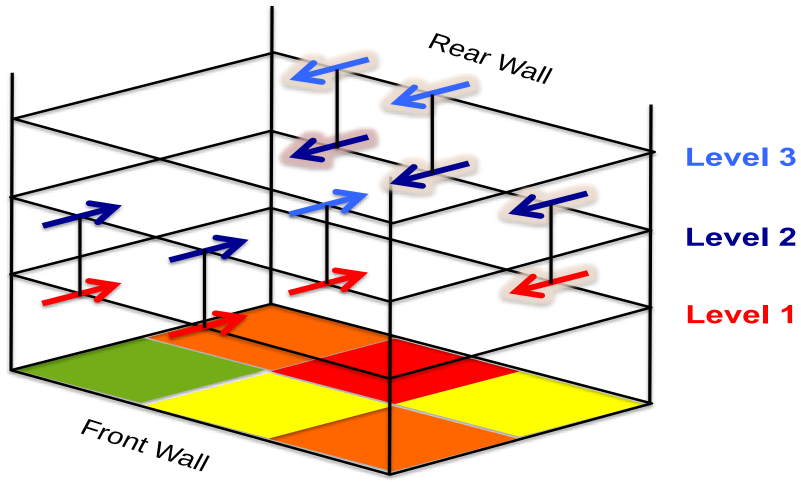



**Figure 4: Schematic Illustrating Temperature-Based Injector Selection**

The optimized injection strategy can be determined by CFD and CKM modeling and field evaluation.

### *3.3 FGR-SNCR*

The FGR-SNCR option incorporates Flue Gas Recirculation (FGR) into the SNCR design.

In this option, a portion of the flue gas from combustion is recirculated from the ID fan inlet duct and is then re-injected back into the furnace through the over-fire air system. FGR is used to replace a portion of the secondary air flow, this reduces use of ambient air and $O_2$ concentration or stoichiometric excess ambient air while still maintaining the secondary air gas flow needed for mixing in the furnace.

The addition of FGR provides additional $NO_X$ emission reduction in several ways:

- Lowers combustion temperatures in the furnace.
- Improves mixing in the furnace; and
- Reduces excess ambient air during the combustion process.

$NO_X$ formation is the inevitable result of combustion. $NO_X$ is formed by three potential mechanisms. The first mechanism entails the high-temperature oxidation of the nitrogen found in the combustion air, and $NO_X$ formed in this manner is called thermal $NO_X$. The second mechanism refers to the oxidation of the nitrogen component in the fuel, and $NO_X$ formed in this manner is called fuel $NO_X$. The final mechanism forms what is called prompt $NO_X$, and is based on reactions between hydrocarbon radicals and molecular nitrogen in the flame zone. Prompt $NO_X$ is a minor contributor to the overall $NO_X$, while fuel $NO_X$ on the other hand, contributes between 50 and 80% of the overall $NO_X$ emissions. The formation of thermal $NO_x$ is described by the Zeldovich Equation:

$$[\mathrm{NO}] = \mathrm{K}_1 e^{\left(-\mathrm{K}_2/\mathrm{T}\right)}[\mathrm{N}_2][\mathrm{O}_2]^{1/2}\mathrm{t} \qquad (9)$$

where, T = temperature, t = time, and $K_1$ and $K_2$ are constants.

According to the above equation, $NO_X$ can be reduced by lowering the average flame temperature as well as the average oxygen concentration. This can be accomplished by adding recirculated flue gas to the combustion air, thus lowering the flame temperature and diluting the local oxygen concentration.

### *3.4 FGR-ASNCR*

It is also possible to combine the FGR technology described in Section 3.3 with the ASNCR technology described in Section 3.2. The implementation of ASNCR by adding additional independent zones of injection and an acoustic pyrometer can provide additional $NO_X$ reduction while controlling the ammonia slip.

### *3.5 Hybrid SNCR-SCR*

The Hybrid SNCR-SCR option utilizes two treatment stages: an SNCR treatment stage followed by an SCR treatment stage. There is a common misconception that, in a hybrid arrangement, the reagent is over-injected in the SNCR stage. In a stand-alone SNCR application, the reducing agent is released at higher temperatures to minimize ammonia slip formation. In hybrid applications, the ammonia slip becomes the reducing agent over the catalyst. As such, the SNCR process is no longer restricted by temperature, and injection at lower temperature is customary to the extent that unit geometry allows it and there is no risk of chemical impingement on the boiler surfaces.

Releasing the chemical at a cooler temperature accomplishes three (3) objectives: it allows the SNCR to achieve lower target $NO_X$ limits, minimizes $NO_X$ formation reactions, and improves chemical utilization. In addition, due to the lower temperature of chemical release, a controlled, but higher concentration of ammonia is available to feed the catalyst. The excess ammonia slip from the first stage then reacts in the presence of the downstream in-duct catalyst located downstream in the flue gas path. In some cases, a static mixer is installed at the economizer outlet to provide the additional mixing required to achieve good $NH_3/NO_X$ distribution across the face of the catalyst.

The combination of these two technologies also allows for a higher $NO_X$ reduction and improved chemical utilization versus a standalone SNCR system. For a standalone SNCR, higher SNCR $NO_x$ reductions are theoretically possible, with the limiting factors being the ability to treat a large percentage of the total flue gas and being restricted by $NH_3$ slip limitations. Perhaps the most advantageous aspect of combining the two technologies is that by having the catalyst behave as an ammonia "mop," one removes the second limitation and increases the potential $NO_x$ reduction efficiency of the SNCR.

Installing an in-duct catalyst downstream of an SNCR has an enabling effect on SNCR performance. The SCR catalyst is typically installed in a high dust environment at the boiler economizer outlet. Urbas explains that "SNCR NOx reduction occurs in a defined temperature window, roughly bell-shaped, with maximum SNCR $NO_X$ reduction occurring at the top, or plateau of the bell. In a commercial 'stand-alone' SNCR, the system is operated within the slope area on the right side of the temperature window curve. In this region, the hot side of the performance maximum, ammonia slip is very low or nonexistent. This is often an operating constraint imposed by the source owner. In contrast, the SNCR component of the hybrid system operates best at the plateau, which is in a lower temperature region. In this region, SNCR $NO_X$ reductions are maximized and some ammonia slip is produced. The ammonia slip that is produced is available for additional $NO_X$ reductions with a downstream catalyst system. When operated in this manner, SNCR $NO_X$ reduction is maximized (compared to its stand-alone performance) and additional $NO_X$ reductions are realized from the catalyst, which is fueled by the SNCR generated ammonia slip [2]." Although this temperature window is a function of the baseline $NO_X$, it typically ranges between 1600°F and 2000°F. The "hot side of the performance maximum," as described above, typically equates to chemical release temperatures in the 2000°F range. The SNCR component of hybrid systems are capable of operating at nominal temperatures in the 1800°F range (and slightly lower). Refer to Figure 3 for an illustration of the bell-shaped temperature curve discussed above. The operating temperature range of the SCR catlayst is generally between 550°F and 750°F. The actual minimum and maximum temperatures depend on the flue gas consitutents, catalyst design requirements, and boiler operation.

A hybrid SNCR-SCR also has a lower capital cost than a full-scale SCR. Given typical conditions, the ductwork modifications needed for a hybrid SNCR-SCR and additional component weights can be accommodated by the existing structural steel without the need for new foundations while far less catalyst is used. In addition, the pressure drop of the system is typically considerably less than for a standalone SCR.

### *3.6 DeNO$_X$ Catalytic Filter Bags*

In lieu of typical Pulse Jet Fabric Filter (PJFF) bags, DeNO$_X$ catalytic filter bags can be utilized with ammonia injection to reduce NO$_X$ in a similar fashion to traditional SCR catalyst. These combination bags remove both dust and gaseous compounds simultaneously. A typical DeNO$_X$ catalytic filter bag is comprised of one to three layers of fabric; one lined with a PTFE membrane and each including its own unique catalytic formula. DeNO$_X$ filter bags provide good resistance to catalyst poisoning, and service life, and pressure drop are both comparable to conventional fabric filters. Typical minimum operating temperatures for catalytic filter bags range from 356°F [3] to 430°F [4] depending on flue gas constituents and catalyst formulation. Note that this range of minimum operating temperatures is not specific to the WTE industry.

### *3.7 Tail-End SCR Systems*

A Tail-End system positions the SCR downstream of all other air pollution control equipment installed on a unit. A major benefit of this installation location is that many of the flue gas constituents that would be damaging to the catalyst have been removed prior to the SCR reactor inlet. However, the installation location results in flue gas temperatures below the acceptable range for catalytic reduction, and the flue gas consequently must be reheated via natural gas or oil burners or steam coil heaters.

The Tail-end SCR process converts the NO$_x$ contained in the flue gas into nitrogen and water with the use of ammonia as the reduction agent. The basic reactions are the following:

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O \tag{10}$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O \tag{11}$$

The following side reactions may occur on a small scale:

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O \tag{12}$$

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \tag{13}$$

The flue gas entering the SCR System typically contains $SO_2$, a portion of which will be catalytically oxidized to $SO_3$, as shown below:

$$2SO_2 + O_2 \rightarrow 2SO_3 \quad (14)$$

The $NO_x$ reduction process requires specifically formulated catalyst to achieve the necessary reaction rates at the available Tail-End SCR operating temperatures, i.e., greater than 450°F. The $NO_x$ reduction efficiency of the catalyst increases with rising temperature. At very high gas temperatures, above ~800°F, the catalyst can be damaged due to sintering. Additional consideration must be taken in the catalyst design to prevent the formation of ammonium bisulfate (ABS) from $SO_3$ and ammonia, a sticky salt that reduces catalyst activity by fouling the catalyst surface. ABS formation only becomes problematic for operation at low temperatures (below the ABS dew point). ABS condensation in the catalyst is a reversible reaction. If the catalyst is heated regularly to typically 320-350°C (608-662°F), the ABS will evaporate, regaining catalyst activity [5].

### 3.7.1 Traditional Tail-End SCR

A Traditional Tail-End SCR operates in much the same way as a high-dust SCR. However, the flue gas temperature at tail-end locations is typically expected to be between 300°F and 330°F. In order to increase the temperature of the flue gas, the SCR is equipped with a gas-gas heat exchanger (GGH), followed by an in-duct burner or steam coil heater to provide the energy required to raise the flue gas temperature to levels required for effective catalyst performance (see Figure 5). This arrangement increases the flue gas temperature for optimal performance by the catalyst, and then the GGH recovers the energy by using the heated gas at the SCR outlet to help increase the temperature of the cooler incoming gas.

Typically, there is leakage across the GGH. Additionally, the heat recovery is approximately 60%.

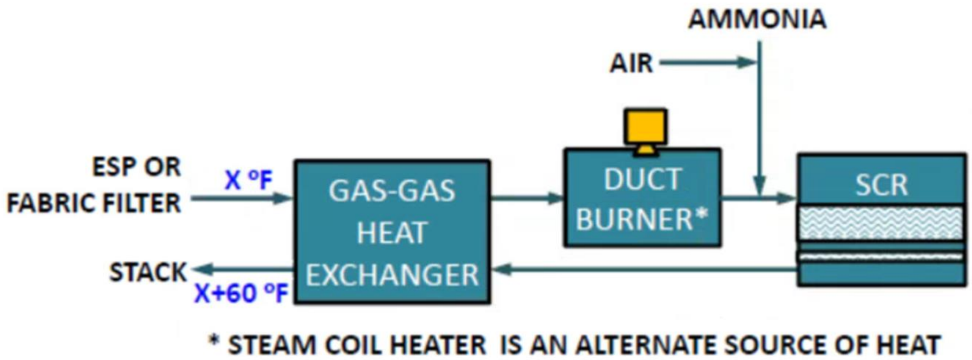



**Figure 5: Traditional Tail-End SCR Arrangement**

In a retrofit, most facilities are not able to overcome the additional pressure loss across the SCR and GGH with existing ID fans. In general, a new booster fan is provided for each reactor to bear the increased draft loss associated with this equipment. In lieu of a new booster fan, replacement or modification of the existing ID fans may also be considered.

### 3.7.2 Regenerative SCR (RSCR)

An RSCR system is designed to reduce $NO_x$, CO and VOCs as a tail-end unit. Similar to the traditional tail-end SCR discussed above, the flue gas temperature is too low to reduce $NO_X$ and oxidize CO/VOC emissions. To increase the temperature of the flue gas, the RSCR system is equipped with either natural gas burners, oil burners, or steam coil heaters to increase the temperature to an acceptable range for the catalytic reduction. To recover the added heat, the RSCR utilizes a heat recovery bed comprised of >95% thermal efficient ceramic media and flue gas directional changes to transfer the heat between canisters.

The RSCR reactor is configured in a canister pair with a heat retention chamber connecting the two canisters, as shown in Figure 6 and Figure 7 below. Each canister has an inlet and outlet damper which directs the flow through the canister pair.

Once the RSCR system is at steady state, the incoming low temperature flue gas will absorb heat from the inlet heat recovery bed to achieve temperatures suitable for emission reduction prior to entering the catalyst. As the flue gas passes through one layer of catalyst, it continues to increase in temperature by passing through the burner flame/steam coil between canisters. As the flue gas exits the second layer of catalyst, it passes through the outlet heat recovery bed where the ceramic thermal media recovers the heat added to the inlet flue gas. The heat recovery beds have greater than 95% thermal efficiency which minimizes the amount of external energy required to offset the heat loss through the system.

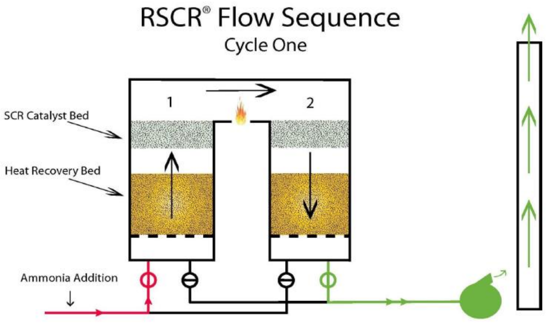



**Figure 6: RSCR Flow Sequence Cycle One [15]**

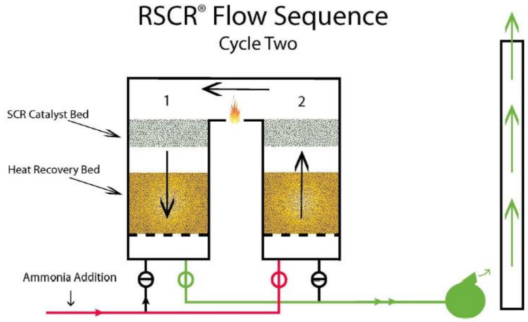



**Figure 7: RSCR Flow Sequence Cycle Two [15]**

As discussed in Section 3.7.1, most facilities cannot overcome the additional pressure loss across the RSCR with existing ID fans in a retrofit. In general, a new booster fan is provided for each reactor to bear the increased draft loss associated with this equipment. In lieu of a new booster fan, replacement or modification of the existing ID fans may also be considered.

# 4.0 TECHNICAL FEASIBILITY OF $NO_X$ CONTROL TECHNOLOGIES

The technical feasibility of each of the technologies discussed in Section 3.0 above was evaluated based on the existing equipment arrangement, system performance, and site constraints of the Baltimore facility. For the purposes of the feasibility study, all values presented in this section were based on a single point steam flow of 191,840 lb/hr, not a range of values. For detailed design, a full fuel analysis, heat input, and fuel throughput range should be analyzed to confirm that the values presented herein are applicable for the entire boiler load range.

## *4.1 Existing SNCR*

CFD models show a large recirculation zone that pushes the flue gas towards the rear wall. This recirculation zone is a result of the geometry of the lower furnace arches and the waterwall platens. The velocity contours suggest that the flue gas velocity is in the 10 to 14 m/s range, leading to reduced residence time and increasing the potential for ammonia slip formation.

The SNCR performance of the Baltimore MWCs is impacted by the presence of the waterwall platens and pendant superheater in the furnace. In order to minimize the risk of impingement on these surfaces and control the ammonia slip, the injectors are placed at a lower elevation thus releasing chemical at higher temperature somewhat limiting the achievable $NO_x$ reduction.

The existing SNCR system can consistently control $NO_X$ to levels below 150 ppmvd @ 7% $O_2$ on a 24-hour block average and 145 ppmvd @ 7% $O_2$ on a 30-day rolling average. The existing SNCR system may be capable of maintaining a controlled $NO_X$ level of 135 ppmvd @ 7% $O_2$ on a 24-hour block average and 130 ppmvd at 7% $O_2$ on a 30-day rolling average while limiting the ammonia slip to approximately 5 ppmvd to avoid a visible ammonium chloride plume. However, the exact magnitude of these values must be confirmed via further tuning. As the City of Baltimore has a 0 visible plume limit, the amount of ammonia slip leaving the system is a critical process parameter. The capture rate of any ammonia slip in the particulate collection system is extremely limited with the existing ESP. This option is technically feasible with further field optimization and tuning.

Overall improvement of the remaining technologies is evaluated against a baseline of the further-optimized controlled $NO_X$ level of 135 ppmvd @ 7% $O_2$ on a 24-hour block average and 130 ppmvd at 7% $O_2$ on a 30-day rolling average.

## *4.2 Advanced SNCR*

Taking into account the presence of the recirculation zone and the need to avoid waterwall platen and superheater impingement from urea injection, injectors will need to be placed at multiple (at least two) elevations for the ASNCR concept to be viable. The average temperature at the 4$^{th}$ floor elevation is 2050°F, so placing injectors below the 4$^{th}$ floor will have the potential to increase $NO_X$ or at least degrade the chemical utilization. The chemical coverage may be improved by adding more injectors on the rear wall at the 4$^{th}$ floor, and also by adding some injectors on the front wall at a slightly higher elevation. The front wall injectors may be releasing a small amount of chemical within the recirculation zone, but these droplets are expected to be fully evaporated by the time they reach the waterwall platens. To eliminate any risk of impingement, the injectors will be placed based on guidance from the CFD and chemical spray modeling that will be done during the design phase. These injectors will be releasing chemical at lower temperature allowing for lower target $NO_X$ levels. The acoustic pyrometer will provide the temperature profile across the entire furnace cross section. It should be noted that when implementing the ASNCR process, the ability to release chemical at a lower temperature is not so much a result of placing injectors at much higher elevations, but rather taking advantage of local, low temperatures across the cross-sectional area and biasing chemical toward that section of the furnace. Similarly, certain injectors will be removed from service if they are spraying in an area where the temperature falls above a design value while other injectors will be operating at different chemical and dilution water flows.

The optimum injector locations cannot be specified at this time as Fuel Tech has not performed the CFD and chemical spray modeling on these units. Based on experience, however, a 5% improvement in chemical coverage is feasible, leading to a target $NO_X$ of 110 ppmvd @ 7% $O_2$ on a 24-hour block average and 105 ppmvd at 7% $O_2$ on a 30-day rolling average while the ammonia slip is kept at the 5 ppm range. It should be noted that without the acoustic pyrometer, this lower level of controlled $NO_X$ would not be feasible at low slip. The anticipated chemical consumption, allowing for baseline swings and higher temperatures, ranges between 35 and 40 gph. An Advanced SNCR (ASNCR) system may be capable of maintaining a controlled $NO_X$ level of 110 ppmvd @ 7% $O_2$ on a 24-hour block average and 105 ppmvd at 7% $O_2$ on a 30-day rolling average while limiting the ammonia slip to 5 ppmvd by incorporating an acoustic pyrometer and by the automatic addition/redistribution of injectors at different elevations as guided by CFD modeling.

This option is technically feasible with future CFD and chemical spray modeling where particular attention will be paid to injector placement so that there is no risk of chemical impingement on the superheater and waterwall platens and other boiler surfaces. An improvement of 25 ppmvd at 7% $O_2$ on a 30-day rolling average can be realized over the optimized existing SNCR.

### *4.3 FGR-SNCR*

The FGR-SNCR option was evaluated using a boiler heat transfer model. FGR rate was limited to 15% of the total flue gas from combustion because of superheat attemperator spray flow rates considerations. The boiler model showed higher FGR rates would increase superheater heat pick up. FGR rates were limited to not increase attemperator spray flow above the attemperator system capacity. FGR allowed stoichiometric excess ambient air to be reduced from 80 -100% down to 60%.

The flue gas for the FGR system will be extracted from the ID fan inlet duct through an FGR fan. The FGR fan will re-inject the flue gas into the over-fire air ports. Some modifications to the units will be needed to install the ductwork and FGR fan. See Appendix B for the Proposed Flue Gas Recirculation Addition modifications. Duct routing must be verified during a detailed analysis to confirm final arrangement feasibility. Additional local analysis of the steel supporting the new ductwork and fan would also be required to determine the extents of any required steel reinforcements. Reinforcements are assumed to be minimal and a nominal tonnage was included in the cost evaluation. It is anticipated that no changes would be required to main steel and existing columns.

The FGR-SNCR option is designed jointly by BPE and Fuel Tech. Fuel Tech has applied SNCR on municipal solid waste combustors equipped with FGR. SNCR systems have been installed on units equipped with FGR worldwide. These applications include multi-pass furnace units such as the Covanta design and single pass furnace units such as the Volund or CNIM designs. FGR tends to impact the thermal and chemical environment of the flue gas by lowering the temperature and baseline $NO_X$, and increasing the CO concentration. Multi-pass furnace units tend to provide longer residence time at temperatures conducive to SNCR than single pass furnace units such as Wheelabrator Baltimore. These parameters are all taken into consideration during the evaluation of the SNCR process and selection of injector locations.

BPI has provided Fuel Tech with an estimate of operating conditions if FGR were to be implemented. The baseline $NO_X$ for the purpose of this study is assumed to be 190 ppmvd at 7% $O_2$, however the exact magnitude and/or range must be confirmed during detailed design. The temperature at the bullnose elevation is expected to be 25°F lower than the base case, while the operating $O_2$ is 1.4% lower on a dry basis than the base case. This lower oxygen may give rise to a slightly higher CO concentration at the point of chemical release, but overall the thermal and chemical environment is not expected to change significantly. Since the acoustic pyrometer will not be in use under this condition, injectors cannot be placed at higher elevations (lower temperature of chemical release) to ensure that the ammonia slip stays under control. Guided by the CFD, however, injectors can be repositioned at the 4$^{th}$ floor elevation thus improving the chemical coverage in excess of 60%.

Based on the performance attained by the existing SNCR system, an FGR-SNCR system should be capable of maintaining a controlled $NO_X$ emissions level of 120 ppmvd @ 7% $O_2$ on 24- hour block average and 115 ppmvd at 7% $O_2$ on a 30-day rolling average while limiting the ammonia slip to 5 ppmvd after redistribution of injectors as guided by CFD modeling and starting from a lower baseline $NO_X$. Since the injectors will only be redistributed at the 4$^{th}$ floor elevation to optimize chemical coverage and will not be placed at a higher elevation due to ammonia slip concerns, the risk of chemical impingement on the superheater platens will be negligible as in the case with the existing SNCR system.

This option is technically feasible from both an arrangement and performance perspective with future CFD modeling. An improvement of 15 ppmvd at 7% $O_2$ on a 30-day rolling average can be realized over the optimized existing SNCR.

### *4.4 FGR-ASNCR*

As mentioned in Section 4.3, the installation of FGR on the Baltimore combustors has the potential of reducing the baseline $NO_X$ to 190 ppmvd at 7% $O_2$. The implementation of ASNCR by adding additional zones of injection and an acoustic pyrometer can provide significant reduction while controlling the ammonia slip. Assuming the same 5% improvement in chemical coverage used for the stand alone ASNCR, a target $NO_X$ of 100 ppmdv at 7% $O_2$ while the ammonia slip is kept at the 5 ppm range is expected to be achievable. The anticipated chemical consumption, allowing for baseline swings and higher temperatures, ranges between 30 and 35 gph. An FGR/ASNCR system should be capable of maintaining a controlled $NO_x$ level of 105 ppmvd @ 7% $O_2$ on a 24-hour block average and 100 ppmvd at 7% $O_2$ on a 30-day rolling average while limiting the ammonia slip to 5 ppmvd. This is accomplished by incorporating an acoustic pyrometer and by the addition/redistribution of injectors at different elevations as guided by CFD modeling while starting from a lower $NO_x$ baseline.

This option is technically feasible from both an arrangement and performance perspective with future CFD modeling. An improvement of 30 ppmvd at 7% $O_2$ on a 30-day rolling average can be realized over the optimized existing SNCR.

### *4.5 Hybrid SNCR-SCR*

As in the case of Advanced SNCR, injectors can be repositioned to achieve better chemical coverage and injectors can be added at slightly higher elevations to target those flue gas temperatures that provide higher utilization without creating concerns about ammonia slip. Based on the geometry of these units, and out of concern for impingement on the front waterwall platens, the SNCR $NO_x$ reduction will be limited to an approximately 10 to 15% increase above the reduction achieved by the existing “as-is” SNCR system by not limiting the slip and without reducing the chemical utilization.

The design of the catalyst component must consider facility requirements for ammonia slip and allowable additional pressure loss. Multiple catalyst vendors were consulted regarding their previous experience with hybrid arrangements, potential issues, catalyst poisons, and typical catalyst life in a high-dust municipal solid waste (MSW) application. Some vendors had no direct experience at all with this arrangement and were unable to provide insight. Those with experience indicate that deactivation is very high in a high-dust environment, and therefore the vendor would be unable to provide any performance guarantees for this arrangement.

For waste to energy facilities firing municipal solid waste, lead and other trace metals are present in the flyash. Lead has been reported to “cause serious catalytic poisoning by either chemical reaction, or by the introduction of a barrier between the gas phase and the active sites [6].” Other publications also suggest that in waste combustion, catalyst must be placed downstream of particulate removal devices in order to prevent fouling [7].

A recent study analyzed SCR catalysts after placing them in a slipstream from an MSW combustion plant. In the most deactivated catalyst, there was a reduction in activity of 94% over a period of 1,951 hours [6].

BPE was unable to locate references of any full-scale Hybrid SNCR-SCR systems installed in the United States in the MSW combustion industry. Due to high deactivation rates of the catalyst and lack of reference installations, the Hybrid SNCR-SCR option is not considered technically feasible for the Baltimore facility.

## 4.6 DeNO$_X$ Catalytic Filter Bags

Several challenges exist with the DeNO$_X$ catalytic filter bag option. The addition of a PJFF will most certainly result in an increase in system pressure loss. ESP installations typically require a pressure drop of approximately 0.5 inches of water column [8] at minimum. PJFF installations typically require a pressure drop of around 4 to 10 inches of water column [9]. While the pressure drop across DeNO$_X$ catalytic filter bags is comparable to traditional PJFF bags, the resulting increase in pressure loss from the exchange of the existing ESPs for new PJFFs will require the upgrade or replacement of the existing ID fans; the currently installed fans are not capable of overcoming the additional loss.

Temperature presents another challenge for catalytic filter bags at the Wheelabrator Baltimore facility. In the current system arrangement, each of the ESPs is located downstream of a Spray Dryer Absorber (SDA). The USEPA states that "optimal temperatures for $SO_2$ removal for dry sorbent injection systems range from 150°C to 180°C (300°F to 350°F) [10]." Data from the facility indicates that from 2016 to 2018, ESP outlet temperatures ranged from 298°F to 313°F. Typical minimum operating temperatures for catalytic filter bags range from 356°F [3] to 430°F [4]. As these filter bags contain catalyst, similar concerns regarding ammonium bisulfate (ABS) exist when operating below the ABS dew point (see Section 3.7). Increase of the SDA operating temperature in order to satisfy the catalytic filter bag temperature requirement would sacrifice $SO_2$ removal and ability to meet the required $SO_2$ limit.

Additionally, the USEPA indicates that, as temperatures approach 350°F, the effectiveness of powdered activated carbon (PAC) reduces rapidly; an increase in ESP inlet temperature from 300°F to 350°F during one study reduced mercury removal from approximately 90% to 10 to 20% [11]. In fact, the ability of most PAC formulations to adsorb mercury begins to deteriorate at 333°F, with a more rapid deterioration beginning at 350°F [12].

Due to operating temperature requirements, the DeNO$_X$ Catalytic Filter Bag option is not considered technically feasible for the Baltimore facility.

## 4.7 Tail-End SCR Systems

<u>System Arrangement Considerations</u>

Potential locations for the tail-end SCR systems at grade are very limited. Sufficient space is not available between the outlet of the ESPs and the inlet of the ID fans at grade. The only available locations for the SCRs at grade are a significant distance from each respective flue gas path and would require a substantial amount of ductwork to and from each SCR. This carries with it not only a large material cost (in ductwork, steel, and foundations), but also an increase in additional pressure drop across the system. For these reasons, this layout is considered to be impractical.

Appendix B includes arrangement drawings detailing this option for the RSCRs (the larger of the tail-end options).

In order to overcome the lengthy ductwork runs of locating the SCRs at grade, placement above the existing ESPs or new PJFFs was considered. This location is more physically feasible. Appendix B includes arrangement drawings detailing this option for both Traditional Tail-End SCRs and RSCRs. Additional evaluations must be performed to determine final feasibility. These evaluations must look at the existing foundations and steel structures as well as ensuring there is adequate space for new foundations and steel required to support the new equipment while maintaining proper access to existing equipment for maintenance. BPE has located several traditional SCRs in a similar fashion (essentially framing them above existing equipment) and has found this to be a viable option when space is limited.

As discussed in Sections 3.7.1 and 3.7.2, installation of a traditional tail-end SCR or RSCR results in increased total system pressure loss. The existing ID fans do not have enough capacity to overcome this increase. The booster fan for each SCR should be located at grade, but this option requires a significant amount of ductwork between the SCRs and the booster fans. BPE believes that replacement of the existing ID fans with new fans capable of overcoming the additional pressure loss is a more practical option for both tail-end options due to the facility space constraints.

For the purposes of this study, both options are investigated in the interest of comprehensiveness.

All Tail-End systems have been evaluated at two (2) upstream conditions:

- Existing upstream ESP remains in service.
- Existing upstream ESP is removed from service and replaced with a PJFF.

BPE Regenerative SCR (RSCR) systems have been installed almost exclusively downstream of ESPs but have not been installed on a Municipal Waste Combustor.

The option of replacing the ESP with a PJFF is being considered with SCR feasibility analysis given that USEPA will be revising the MWC standards in future years that could require ESP replacement. In this case, it would be practical to install PJFF along with new SCR to avoid significant engineering construction difficulties and costs with replacing ESPs after SCR installation.

Installation of tail-end systems over the existing ESPs also presents several arrangement obstacles. The Baltimore facility requires full access to the ESP roof for maintenance activities, including replacement of collection plates, rigid frame discharge electrodes and transformer/rectifier (TR) sets. In order to access the aforementioned items, the ESP roof must be removed. Installing a tail-end system over the existing ESPs eliminates the ability for the plant to continue their current method of maintenance. Additional maintenance methods such as monorails can be difficult in nature due to side clearances and drop zones and material handling with multiple ESPs installed in parallel. For this study, BPE has assumed a TR set height of roughly 9.5 feet above the ESP roof based on scaling available drawings. BPE has allowed for 11.5 feet between the top of the TR set and the bottom of the outlet duct for the traditional tail-end SCR option and 18.5 feet between the top of the TR set and the bottom of the ductwork for the RSCR option. Note that for the traditional tail-end SCR option the main SCR support steel would be located an additional 11.5 feet higher than the bottom of the duct, which could then be hung from the same steel. If additional clearance was required, layouts with offset ductwork could be looked at such that the ducts were not directly over the TR sets. The above clearances also assumed the new equipment to be no higher than the top of the existing SDA inlet duct. BPE feels that with between 11.5 feet and 18.5 feet of clearance there is adequate room for support steel, monorails, and equipment removal. Final determination of equipment elevations, clearances, layouts, and maintenance requirements would need to be evaluated in more depth in the next phase to confirm.

System Inlet and Outlet $NO_X$

An SCR Inlet $NO_X$ of 212 ppmvd @ 7% $O_2$ is assumed for the Tail-End systems. Outlet $NO_X$ values are based on the Best Available Control Technology (BACT) Review [13] and Final Permit [14] for the Palm Beach Renewable Energy Facility No. 2 (PBREF-2) WTE plant located in West Palm Beach, Florida. The evaluation and permit establish the BACT for $NO_X$ emissions from MWC each unit as 50 ppmvd @ 7% $O_2$ (24-hour block arithmetic mean) and 45 ppmvd @ 7% $O_2$ (12-month rolling average) with a Tail-End SCR installed. An ammonia slip value of 10 ppmvd @ 7% $O_2$ is also based on the PBREF-2 BACT Review [13] and Final permit [14].

### 4.7.1 Traditional Tail-End SCR

For both the upstream ESP and upstream PJFF conditions, each of the three (3) SCRs requires two (2) initial catalyst layers in a three (3) module wide by four (4) module deep arrangement. Space for one (1) future spare layer is also provided. Catalyst with a pitch of 4.9 mm is assumed under both conditions. The duct burner or steam coil heater must heat the flue gas to 500°F for optimal catalyst performance.

This option is technically feasible from both an arrangement and performance perspective with the caveats noted in Section 4.7 above.

Refer to Appendix B for arrangement drawings for the Traditional Tail-End SCR.

### 4.7.2 Regenerative SCR (RSCR)

For the upstream ESP condition, each of the three (3) RSCRs requires three (3) reactors (three (3) pairs of canisters) with a 5.9 mm pitch catalyst, with a total of 64 catalyst modules provided per unit.

For the upstream PJFF condition, each of the three (3) RSCRs requires two (2) reactors (two (2) pairs of canisters) with a 3.3 mm pitch catalyst, with a total of 48 catalyst modules provided per unit.

Note that the difference in catalyst pitch between the upstream ESP condition and the upstream PJFF condition is due to the higher dust capture efficiency of the PJFF. A grain loading of 0.03 – 0.04 gr/dSCF was assumed for the upstream ESP condition, while a grain loading of 0.006 gr/dSCF was assumed for the upstream PJFF condition.

The duct burner or steam coil heater must heat the flue gas to 465°F for optimal catalyst performance, however, for $SO_3$ approaching 0.3 ppmvd the temperature must be around 575°F in order to avoid ABS formation. The economics of operation may justify allowing the ABS to form and then be decomposed. It should be noted that separate catalyst suppliers were consulted for the Traditional Tail-End and RSCR options. This resulted in different operating temperatures for each technology. The ideal operating temperature for a chosen technology would be evaluated and determined during the detailed design phase of a project.

This option may be considered technically feasible from both an arrangement and performance perspective subject to additional analysis to determine final feasibility with respect to adequacy of the existing foundations and steel structures. Further analysis must also ensure that adequate space for new foundations and steel required to support the new equipment is available, while maintaining proper access to existing equipment for maintenance (see Section 4.7 above). BPE has worked on multiple projects where foundation mini piles, foundation bridges, etc., have been used reinforce existing foundations and bridge over obstructions in order to support new steel in tight locations. Based on past experience, it is believed that this is a workable solution to the additional load and steel structure required to support the new tail end equipment.

Refer to Appendix B for arrangement drawings for all RSCR options.

## 5.0 ESTIMATED CAPITAL AND OPERATING COSTS

Although many of the technologies discussed in this study are technically feasible, the cost of each technology must be weighed against the relative improvement of $NO_X$ reduction to determine financial feasibility. As mentioned previously, detailed engineering, design, and construction of essential project parameters such as electrical work, civil work (foundations, pilings, site preparation), and balance of plant for integrating the various $NO_X$ control technologies into existing plant have not been technically evaluated as a part of this feasibility study. However, costs for these have been considered per industry standards in the estimation of capital costs. Estimated Budget pricing for each technically feasible option is presented in Sections 5.1 through 5.5. Expected annual operating costs for reagent, steam, and significant power consumptions are also presented in Section 5.6.

### *5.1 Existing SNCR*

Estimated Budget Price for Startup, Optimization, and Training [e]

$85,200.

Eighty-Five Thousand Two Hundred Dollars

### *5.2 Advanced SNCR*

Estimated Budget Price for Materials, Equipment, and Installation Including:

Equipment Design and Project Team Labor [f]

Startup, Optimization, and Training [f]

Baseline Testing and CKM/CFD Modeling [e]

Replace and Upgrade SNCR Metering Modules [e]

Six (6) NOxOUT Injectors for 2$^{nd}$ Injection Level [e]

Acoustic Monitoring System [e]

Six (6) Boiler Tube Panels for New Injectors [f]

Boiler Tube Panels for Acoustic Monitoring System [f]

Piping Valves and Specialties [f]

Instrumentation [f]

$8,665,162.

Eight Million Six Hundred Sixty-Five Thousand One Hundred and Sixty-Two Dollars

### *5.3 FGR-SNCR*

Estimated Budget Price for Materials, Equipment, and Installation Including:

Equipment Design and Project Team Labor [f]

Startup, Optimization, and Training [f]

Baseline Testing and CKM/CFD Modeling [e]

Ductwork [f]

Structural Steel [f]

FGR Fans [e]

Expansion Joints and Dampers [f]

Piping Valves and Specialties [f]

Instrumentation [f]

$5,829,591.

Five Million Eight Hundred Twenty- Nine Thousand Five Hundred and Ninety-One Dollars

### *5.4 FGR-ASNCR*

Estimated Budget Price for Materials, Equipment, and Installation Including:

Equipment Design and Project Team Labor [f]

Startup, Optimization, and Training [f]

Baseline Testing and CKM/CFD Modeling [e]

Replace and Upgrade SNCR Metering Module [e]

Six (6) NOxOUT Injectors for 2nd Injection Level [e]

Acoustic Monitoring System [e]

Six (6) Boiler Tube Panels for New Injectors [f]

Boiler Tube Panels for Acoustic Monitoring System [f]

Ductwork [f]

Structural Steel [f]

FGR Fans [e]

Expansion Joints and Dampers [f]

Piping Valves and Specialties [f]

Instrumentation [e]

$12,993,524.

Twelve Million Nine Hundred Ninety -Three Thousand Five Hundred and Twenty-Four Dollars

## *5.5 Tail-End SCR Systems*

For the traditional tail-end SCR and the regenerative SCR (RSCR), feasibility was investigated for both preserving the existing ESPs as well as r replacing the existing ESPs with a PJFFs. As noted in Section 4.7, additional evaluations must be performed to determine final feasibility. This includes evaluation of existing foundations and steel structures and to ensure adequate space for new foundations and steel required to support the new equipment while maintaining proper access to existing equipment for maintenance. BPE has worked on multiple projects were foundation mini piles, foundation bridges, etc., have been used reinforce existing foundations and bridge over obstructions in order to support new steel in tight locations. Based on past experience, it is believed that this is a workable solution to the additional load and steel structure required to support the new tail end equipment.

Pricing for all tail-end SCR systems (both traditional and RSCR) assumes 19% aqueous ammonia as reagent based on BPE's historical installations.

### 5.5.1 Traditional Tail-End SCR with Existing ESP [k]

Estimated Budget Price for Materials, Equipment, and Installation Including:

Equipment Design and Project Team Labor [f]

Physical Flow Model [f]

Startup, Optimization, and Training [f]

Traditional Tail-End SCR [f]

Catalyst [e]

Steam Coil Heaters [f,j]

Ductwork [f]

Structural Steel [f]

Gas to Gas Heat Exchanger [f]

Aqueous Ammonia System [f]

ID Fans [f]

Expansion Joints and Dampers [f]

Piping Valves and Specialties [f]

Babcock Power
ENVIRONMENTAL
a Babcock Power Inc. company

Instrumentation [f]

$60,574,340.

Sixty Million Five Hundred Seventy-Four Thousand Three Hundred and Forty Dollars

### 5.5.2 Traditional Tail-End SCR with New PJFF

Estimated Budget Price for Materials, Equipment, and Installation Including:

Equipment Design and Project Team Labor [f]

Physical Flow Model [f]

Startup, Optimization, and Training [f]

Traditional Tail-End SCR [f]

Catalyst [e]

Steam Coil Heaters [f,j]

Ductwork [f]

Structural Steel [f]

Gas to Gas Heat Exchanger [f]

Aqueous Ammonia System [f]

ID Fans [f]

PJFF [f]

Expansion Joints and Dampers [f]

Piping Valves and Specialties [f]

Instrumentation [f]

$92,929,377.

Ninety-Two Million Nine Hundred Twenty-Nine Thousand Three Hundred and Seventy-Seven Dollars

### 5.5.3 Regenerative SCR (RSCR) with Existing ESP [k]

Estimated Budget Price for Materials, Equipment, and Installation Including:

Equipment Design and Project Team Labor [f]

Startup, Optimization, and Training [f]

Regenerative SCR - 6 Canister [f]

Catalyst [e]

Ductwork [f]

Structural Steel [f]

Aqueous Ammonia System [f]

ID Fans [f]

Expansion Joints and Dampers [f]

Piping Valves and Specialties [f]

Instrumentation [f]

$76,278,652.

Seventy-Six Million Two Hundred Seventy-Eight Thousand Six Hundred and Fifty-Two Dollars

### 5.5.4 Regenerative SCR (RSCR) with New PJFF

Estimated Budget Price for Materials, Equipment, and Installation Including:

Equipment Design and Project Team Labor [f]

Startup, Optimization, and Training [f]

Regenerative SCR - 4 Canister [f]

Catalyst [e]

Ductwork [f]

Structural Steel [f]

Aqueous Ammonia System [f]

ID Fans [f]

PJFF [f]

Expansion Joints and Dampers [f]

Piping Valves and Specialties [f]

Instrumentation [f]

$92,161,155.

Ninety-Two Million One Hundred Sixty-One Thousand One Hundred and Fifty-Five Dollars

Notes on Budget Pricing

a. Pricing is Indicative Budget Pricing +/- 20%
b. Budget pricing shown is for three units
c. Pricing does not have a validity date due to budget pricing
d. Freight to Wheelabrator Baltimore Facility Site is included
e. Supplier solicited budget pricing
f. Recent, scaled, or allowance pricing
g. Installation estimates are based on 1.00 to 1.25 times material pricing, 4% to 5% total project cost for civil and site activities, and 4% to 5% total project costs for demolition (BPE, [1], Wheelabrator).
h. Pricing does not include Taxes
i. Pricing does not include permitting costs
j. BPE has traditionally supplied natural gas or oil-fired burners. However, BPE is capable of designing this system with steam coil heaters.
k. Pricing does not include additional costs associated with maintenance modifications required for ESP access.
l. Pricing does not include Wheelabrator internal project costs.

**Material**

The prices established herein are subject to adjustment in favor of seller to the extent of increases in applicable taxes, duties, tariffs, and/or similar charges that apply to seller or are otherwise to be borne by seller and become applicable after the date of this order but prior to delivery of all goods and/or services to the purchaser. Recent steel and aluminum tariffs imposed by the United States may impact seller's cost and/or schedule of procurement underlying this proposal/agreement. Seller shall promptly notify purchaser of any change to its price and/or schedule as a result of these changes outside its control and purchaser shall be responsible for the impact of such changes.

### *5.6 Estimated Annual Operating Costs*

The expected annual operating costs for reagent, steam, and significant power consumptions for those technologies deemed technically feasible are outlined in Table 1 below.

**Table 1: Expected Annual Operating Costs for $NO_X$ Control Technologies[1]**

| Technology | Urea (50 wt%)[2,3] | Aqueous Ammonia (19 wt%)[4] | Steam[2,3] | Lost Electrical Revenue[2,3,5] | |
|---|---|---|---|---|---|
| Existing SNCR[6] | $695,000 | | | | |
| Advanced SNCR | $995,000 | | | | |
| FGR-SNCR | $735,000 | | | 0.3 MW | $80,000 |
| FGR-ASNCR | $955,000 | | | 0.3 MW | $80,000 |
| RSCR over Existing ESP | | $500,000[7] | $320,000 | 1.3 MW | $355,000 |
| RSCR over New PJFF | | $500,000[7] | $285,000 | 1.3 MW | $355,000 |
| Traditional Tail-End SCR[8] | | $500,000[7] | $1,280,000 | 1.3 MW | $355,000 |

**Table 2: Wheelabrator Costs[3]**

| | | |
|---|---|---|
| Urea[9] | $1.19 | per gallon |
| Aqueous Ammonia (19 wt%)[4] | $0.78 | per gallon |
| Power[10] | $33.15 | per MW |
| Turbine/Generator Conversion Rate[11] | 9.06 klbs | per MW |

1 All annual operating costs assume availability of the Baltimore Facility of 92%.
2 Expected annual operating costs and expected lost electrical revenue presented as total cost for all three (3) MWC units.
3 Power pricing for lost electrical revenue, urea price per gallon, and cost of diverting steam provided by Wheelabrator. See Table 2 for data.
4 Aqueous ammonia price per gallon based on October 2019 correspondence with Airgas Specialty Products [19].
5 Lost electrical revenue due to fan auxiliary power increase with new technology installation.
6 With further optimization and tuning.
7 Assuming existing SNCR is taken out of service.
8 Traditional Tail-End SCR operating costs are comparable for installation over both existing ESP and new PJFF.
9 Cost in 2020.
10 Average rate budgeted for 2020. To determine lost electrical revenue with installation of SCR.
11 For estimating lost electrical generation for diverting steam for SCR reheat.

**Table 3: Expected Urea & Aqueous Ammonia Usage**

| Technology | Urea (50 wt%)[12,13] | Aqueous Ammonia (19 wt%) |
|---|---|---|
| Existing SNCR[14] | 72 gal/hr | |
| Advanced SNCR | 105 gal/hr | |
| FGR-SNCR | 77 gal/hr | |
| FGR-ASNCR | 100 gal/hr | |
| RSCR over Existing ESP | | 80 gal/hr[15] |
| RSCR over New PJFF | | 80 gal/hr[15] |
| Traditional Tail-End SCR[16] | | 80 gal/hr[15] |

### *5.7 Catalyst Replacement Cost*

For tail-end systems, catalyst must be replaced at the end of its life. Estimated replacement costs for tail-end systems are:

**Table 4: Catalyst Replacement Cost for Tail-End SCR Systems**

| Technology | Replacement Cost[17] | Frequency[18] |
|---|---|---|
| RSCR over Existing ESP | $3,000,000 | 16,000 hours |
| RSCR over New PJFF | $1,600,000 | 16,000 hours |
| Traditional Tail-End SCR[16] | $700,000 | 24,000 hours |

12 Expected annual operating costs and expected lost electrical revenue presented as total cost for all three (3) MWC units.
13 Power pricing for lost electrical revenue, urea price per gallon, and cost of diverting steam provided by Wheelabrator. See Table 2 for data.
14 With further optimization and tuning.
15 Assuming existing SNCR is taken out of service.
16 Traditional Tail-End SCR operating costs are comparable for installation over both existing ESP and new PJFF.
17 Catalyst replacement costs shown are material costs only. Installation, labor, and catalyst disposal or regeneration cost are not included.
18 Replacement necessary at end of catalyst life, indicated in "Frequency" column.

# 6.0 ESTIMATED PROJECT SCHEDULE

High-level estimated project schedules were developed for all options deemed feasible in this study. The schedules do not include time for obtaining state and local permits and approvals. Permitting may add 6-12+ months to the schedule for tail-end SCR systems given the extensive nature of these types of retrofits. Preliminary schedules are presented in Appendix A for the following options:

- Existing SNCR
- Advanced SNCR (ASNCR)
- FGR-SNCR
- FGR-ASNCR
- Tail-End SCR Systems
    - Traditional Tail-End SCR with Existing ESP
    - Traditional Tail-End SCR with New PJFF
    - Regenerative SCR (RSCR) with Existing ESP
    - Regenerative SCR (RSCR) with New PJFF

## *6.1 Construction Approach for New PJFF Options*

The preliminary schedules in Appendix A take the construction of new PJFFs into consideration.

For all Tail-End SCR systems (both traditional and RSCR) with new PJFFs, the suggested approach is to build the new PJFF and tail-end equipment and support structure for Unit 3 first, locating it to the north of the existing Unit 3 ESP. Once major construction is complete, a tie in outage will be used to tie the Unit 3 boiler to the new PJFF and tail-end SCR equipment. The Unit 3 ESP can then be demolished and construction of the new Unit 2 PJFF and tail-end equipment can be installed in its place. This methodology would continue towards the south until all existing units are tied into their new PJFF and tail-end SCR components. This essentially shifts all particulate control equipment north by one unit.

## 7.0 REFERENCES

[1] U.S. Energy Information Administration, "Capital Cost Estimates for Utility Scale Electricity Generating Plants," Washington, DC, November 2016.

[2] Urbas, Jerry B., "Hybrid Selective Non-Catalytic Reduction (SNCR) / Selective Catalytic Reduction (SCR) Demonstration for the Removal of NOx from Boiler Flue Gases," 1999.

[3] Haldor Topsoe, "CataFlex," [Online]. Available: https://www.topsoe.com/chan-pin/cui-hua-ji/cataflextm. [Accessed 24 June 2019].

[4] W.L. Gore & Associates, Inc., "GORE DeNOx Catalytic Filter Bags," [Online]. Available: https://www.gore.com/system/files/2018-07/GORE_DeNOx_Catalytic_Filter_Bags_Data-Sheet.pdf. [Accessed 24 June 2019].

[5] A. R. Nielsen, K. Beldring, T. Slabiak and H. Jensen-Holm, "SCR DeNOx catalyst experience from waste-to-energy plants," January 2018.

[6] J. Brandin and C. Odenbrand, "Deactivation and Characterization of SCR Catalysts Used in Municipal Waste Incineration Applications," *Catalysis Letters,* vol. 148, no. 1, pp. 312-327, 2018.

[7] National Research Council, Waste Incineration and Public Health, Washington, DC: The National Academies Press, 2000.

[8] United States Environmental Protection Agency, EPA Air Pollution Control Cost Manual, Research Triangle Park, NC, 2002, pp. 3-33 - 3-34.

[9] Air & Waste Mangement Association (AWMA), Air Pollution Engineering Manual, New York: Van Nostrand Reinhold, 1992.

[10] United States Environmental Protection Agency, *Air Pollution Control Fact Sheet - Flue Gas Desulfurization (FGD) - Wet, Spray Dry, and Dry Scrubbers,* 2003.

[11] United States Environmental Protection Agency, "Control of Mercury Emissions from Coal Fired Electric Utility Boilers: An Update," Research Triangle Park, 2005.

[12] Sankey, Mark R.; Golden, Michelle; Koza, Donald, Bechtel Power Corp., "Challenges to Mercury Emissions Compliance at New and Existing Coal Fired Power Plants," *Power Engineering,* vol. 117, no. 8, 2013.

[13] Florida Department of Environmental Protection, "Technical Evaluation & Preliminary Determination - DEP File No. 0990234-017-AC (PSD-FL-413)," 15 November 2010. [Online]. Available: http://arm-permit2k.dep.state.fl.us/psd/0990234/U00000317.pdf. [Accessed 01 October 2019].

[14] Florida Department of Environmental Protection, "Air Permit No. 0990234-032-AC/PSD-FL-413C," 29 December 2014. [Online]. Available: https://arm-

permit2k.dep.state.fl.us/adh/prod/pdf_permit_zip_files/0990234.032.AC.F_pdf.zip. [Accessed 01 October 2019].

[15] R. Abrams and R. Faia, "RSCR System to Reduce NOx Emissions from Boilers," in *17th Annual North American Waste to Energy Conference*, Chantily, VA, 2009.

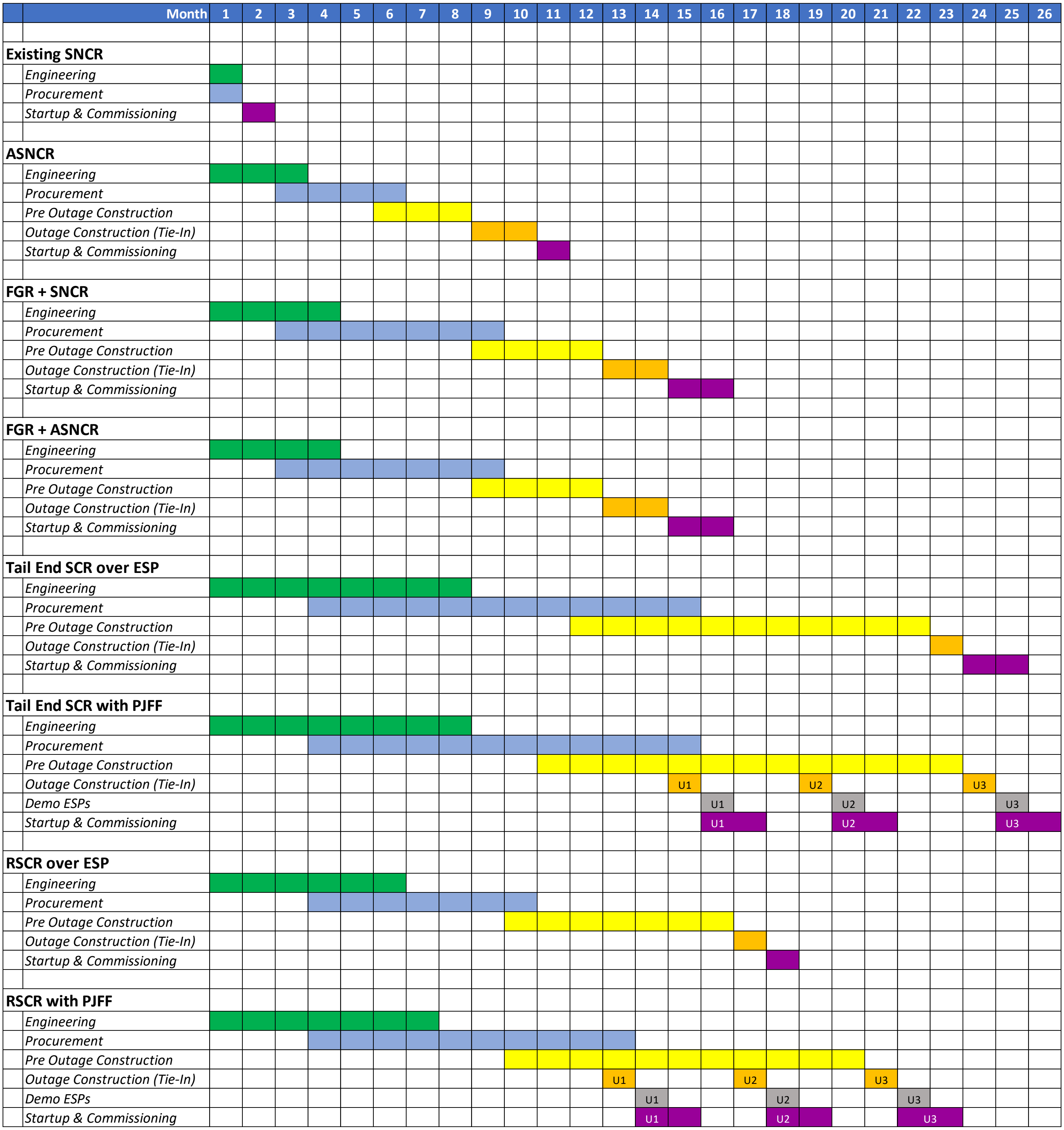
[16] U.S. Energy Information Administration, "Maryland Natural Gas Industrial Price," [Online]. Available: https://www.eia.gov/dnav/ng/hist/n3035md3m.htm. [Accessed 1 August 2019].

[17] ARC, "Amager Ressource Center," [Online]. Available: https://www.a-r-c.dk/amager-bakke#r%C3%B8grensning. [Accessed 04 October 2019].

[18] International Solid Waste Association (ISWA), "Waste to Energy State of the Art Report, 6th Edition," 2012.

[19] R. Johnston, Airgas Specialty Products, *Re: New Entry: Request a Quote*, Personal Email, 2019.

# APPENDIX A PRELIMINARY SCHEDULE



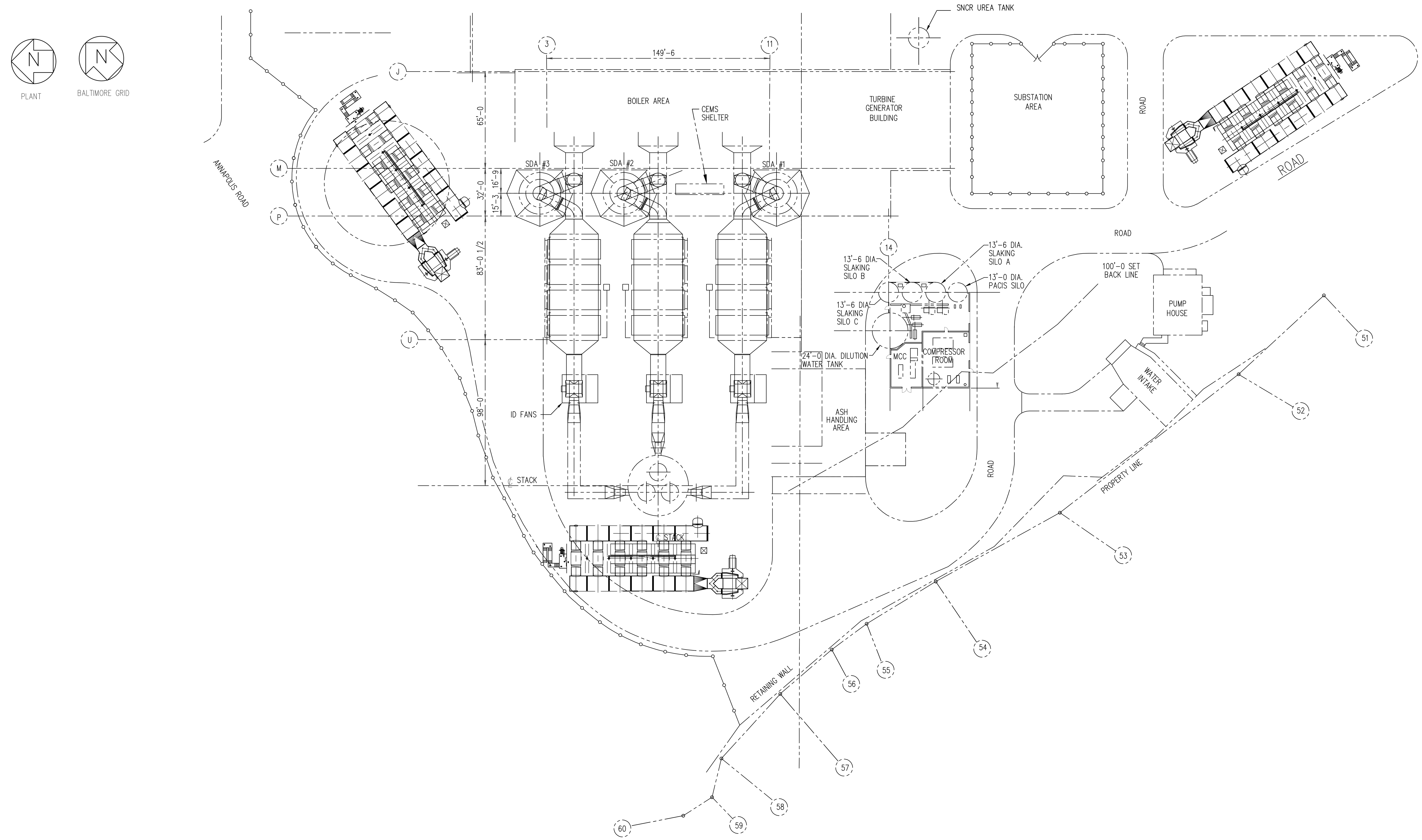
# APPENDIX B ARRANGEMENT DRAWINGS

The table below summarizes the arrangement drawings provided in this Appendix for a number of the options presented in this study.

**Table 5: Arrangement Drawings**

| Document Number | Description |
|---|---|
| 100825-0926750100 | Proposed RSCR Addition – RSCR at Grade |
| 100825-0926750110 | Proposed RSCR Addition – RSCR above Precipitators |
| 100825-0926750111 | Proposed RSCR Addition – RSCR above Precipitators – Elevation View Looking North |
| 100825-0926750120 | Proposed RSCR – Fabric Filter Addition – Elevation View Looking North |
| 100825-0926750121 | Proposed RSCR – Fabric Filter Addition – Plan View A-A |
| 100825-0926750122 | Proposed RSCR – Fabric Filter Addition – Plan Section B-B |
| 100825-0926750123 | Proposed RSCR – Fabric Filter Addition – Elevation View C-C |
| 100825-0926750130 | Proposed Flue Gas Recirculation Addition |
| 100825-0926750140 | SCR, Airheater & Fabric Filter Addition – Elevation View Looking North |
| 100825-0926750141 | SCR, Airheater & Fabric Filter Addition – Plan View A-A |
| 100825-0926750142 | SCR, Airheater & Fabric Filter Addition – Plan Section B-B |
| 100825-0926750143 | SCR, Airheater & Fabric Filter Addition – Elevation View C-C |
| 100825-0926750150 | SCR & Airheater Addition – Above Existing Precipitator – Elevation View Looking North |

DWG. NO. 100825-0926750100




PRELIMINARY
7/9/19

| REVISION | NO. | BY | CHK | DATE | APP'D | DATE |
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THIS DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS IT CONTAINS DATE AND SIGNATURE OF APPROVAL AND THE COMPANY RESERVES THE RIGHT TO CORRECT ANY ERRORS OR OMISSIONS PRIOR TO ACTUAL START OF WORK.

RELEASED & APPROVED ____ DATE ____

THIRD ANGLE PROJECTION

DO NOT SCALE
USE DIMENSIONS ONLY

IFI

DRAWN A. Crowley
DATE 06/20/2019
CHECKED
DATE
APP'D
DATE
SCALE 1/32 IN. = 1 FT.

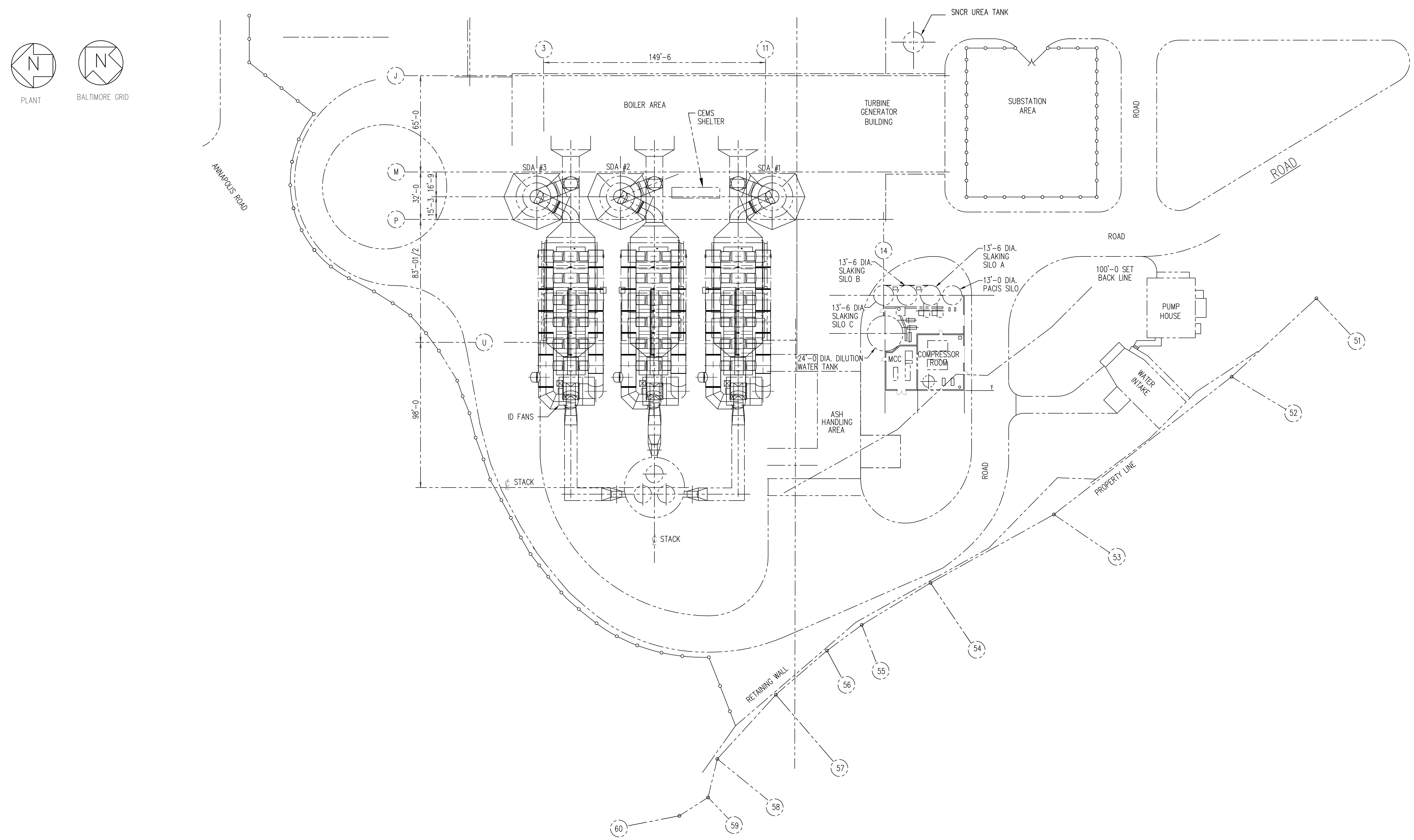
**BABCOCK POWER ENVIRONMENTAL INC.**

PROPOSED RSCR ADDITION
RSCR AT GRADE

WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825-0926750100
REV. NO. P0

DWG. NO. 100825–0926750110

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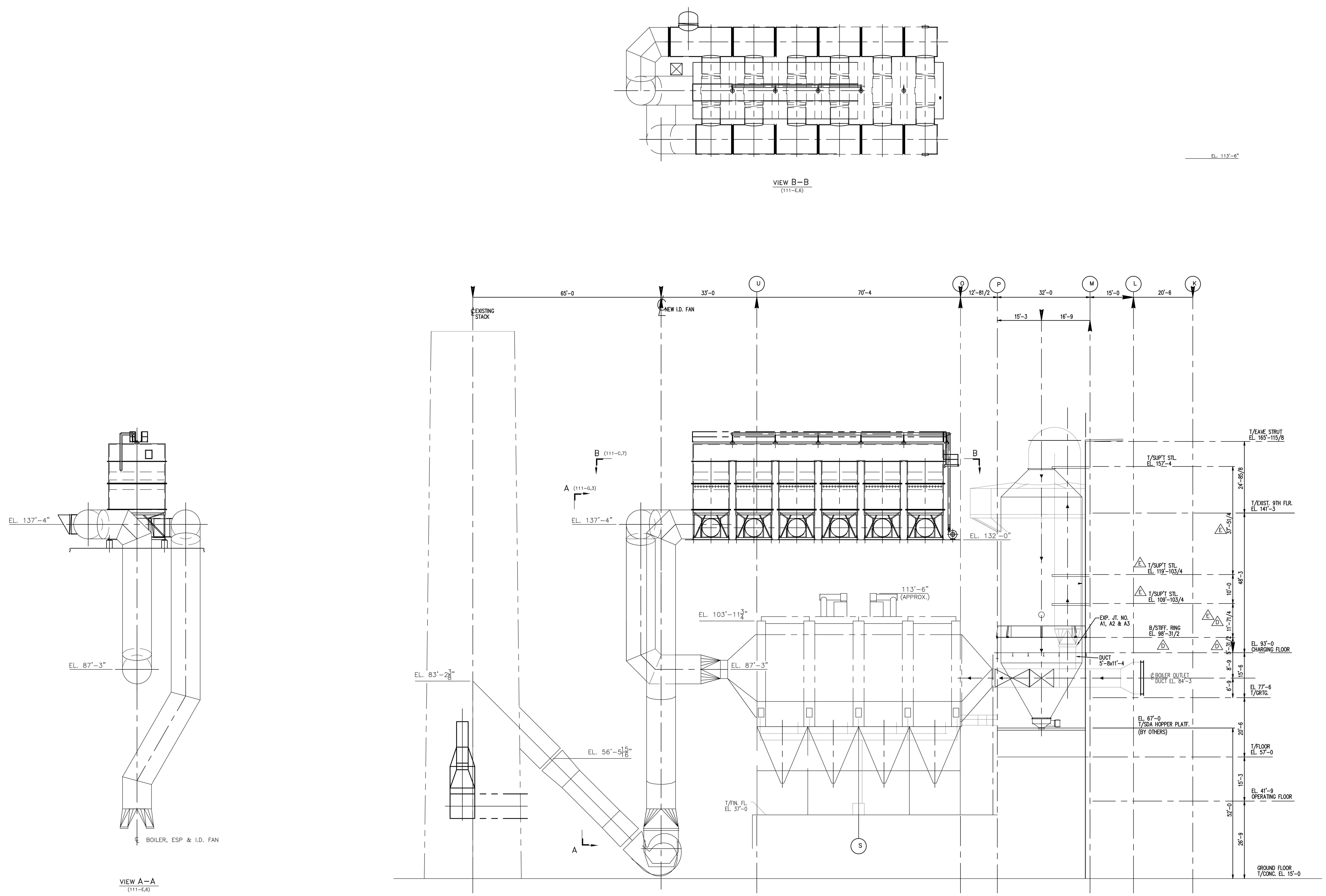
**BABCOCK POWER ENVIRONMENTAL INC.**

PROPOSED RSCR ADDITION
RSCR ABOVE PRECIPITATORS

WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750110 REV. NO. P0

DWG. NO. 100825-0926750111




SIDE ELEVATION

LOOKING PLANT NORTH

PRELIMINARY
11/5/19

| REVISION | NO. | BY | CHK | DATE | APP'D | DATE |
|---|---|---|---|---|---|---|
| ADDED TR SETS. RAISED RSCR. | P1 | AC | – | – | – | – |



THIS DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS IT CONTAINS DATE AND SIGNATURE OF APPROVAL AND THE COMPANY RESERVES THE RIGHT TO CORRECT ANY ERRORS OR OMISSIONS PRIOR TO ACTUAL START OF WORK.

RELEASED & APPROVED DATE

THIRD ANGLE PROJECTION

DO NOT SCALE
USE DIMENSIONS ONLY

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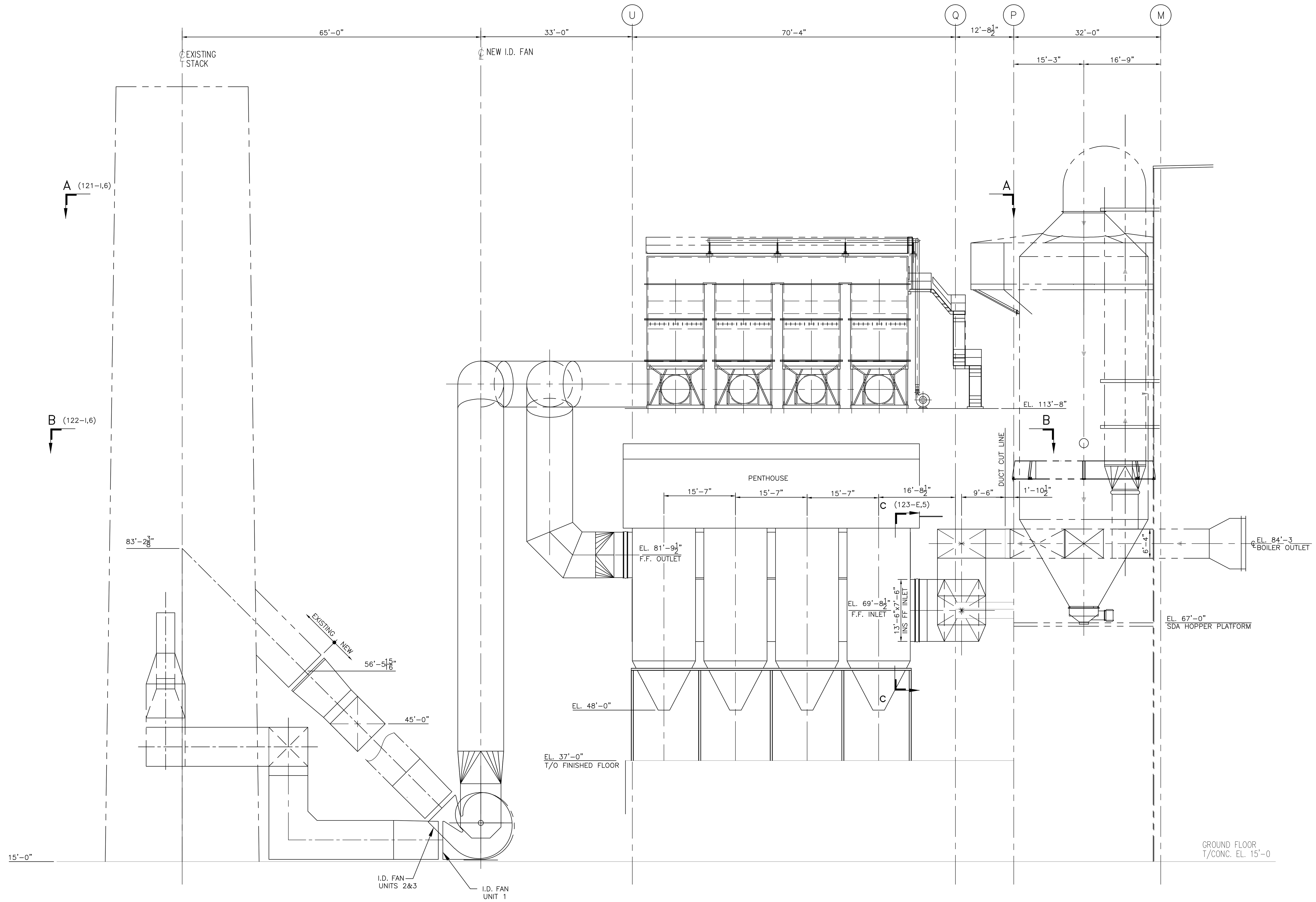
SCALE 1/16 IN. = 1 FT.

**BABCOCK POWER ENVIRONMENTAL INC.**

PROPOSED RSCR ADDITION
RSCR ABOVE PRECIPITATOR
ELEVATION VIEW LOOKING NORTH
WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825-0926750111 REV. NO. P1

DWG. NO. 100825–0926750120




ELEVATION VIEW
PLANT VIEW NORTH

PRELIMINARY
6/26/19

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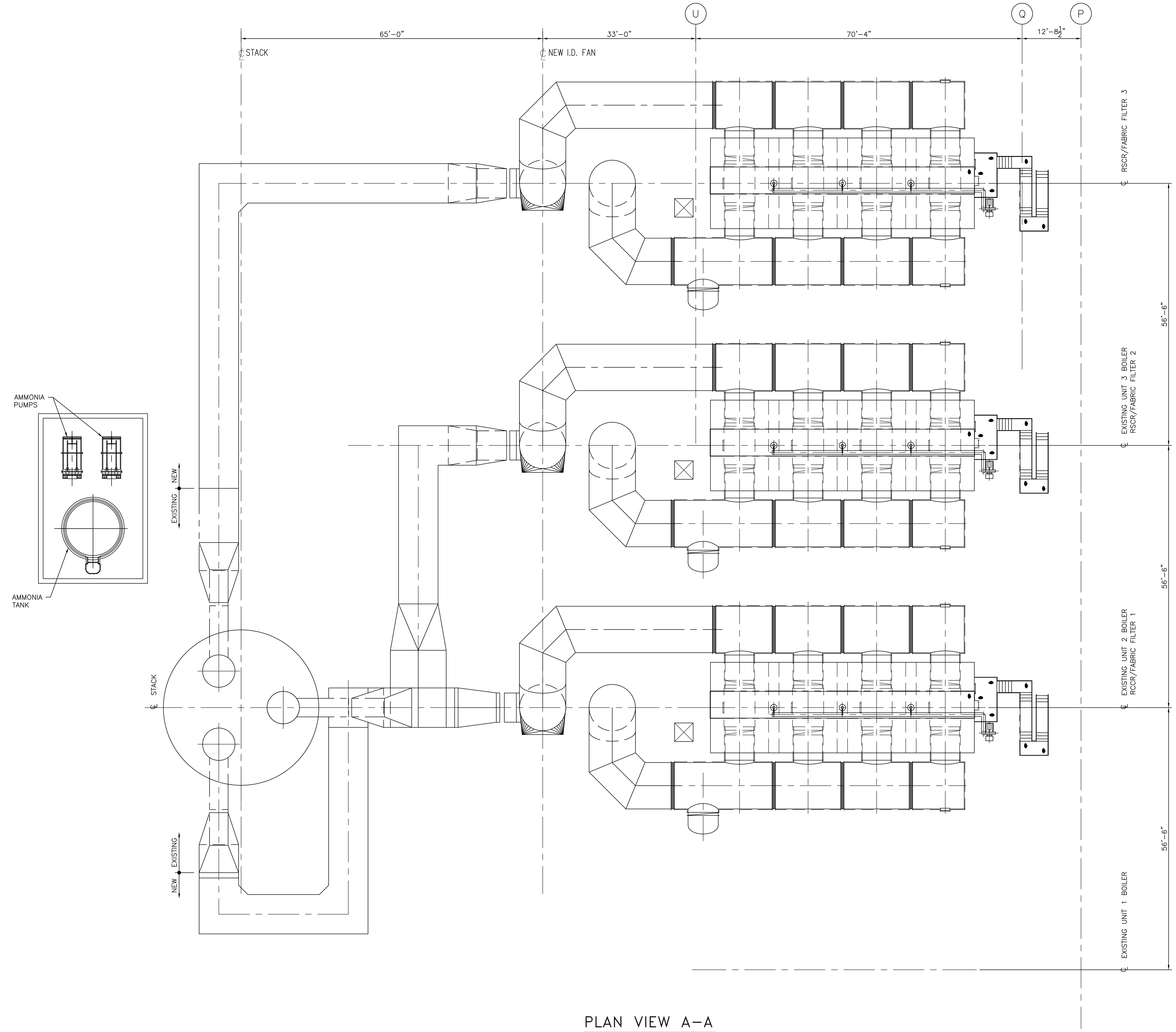
**BABCOCK POWER ENVIRONMENTAL INC.**
PROPOSED RSCR – FABRIC FILTER ADDITION
ELEVATION VIEW LOOKING NORTH
WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND
DWG. NO. 100825–0926750120
REV. NO. P0

DWG. NO. 100825–0926750121




PLAN VIEW A–A
(120–C,2)

PRELIMINARY
6/26/19

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THIRD ANGLE PROJECTION

DO NOT SCALE
USE DIMENSIONS ONLY

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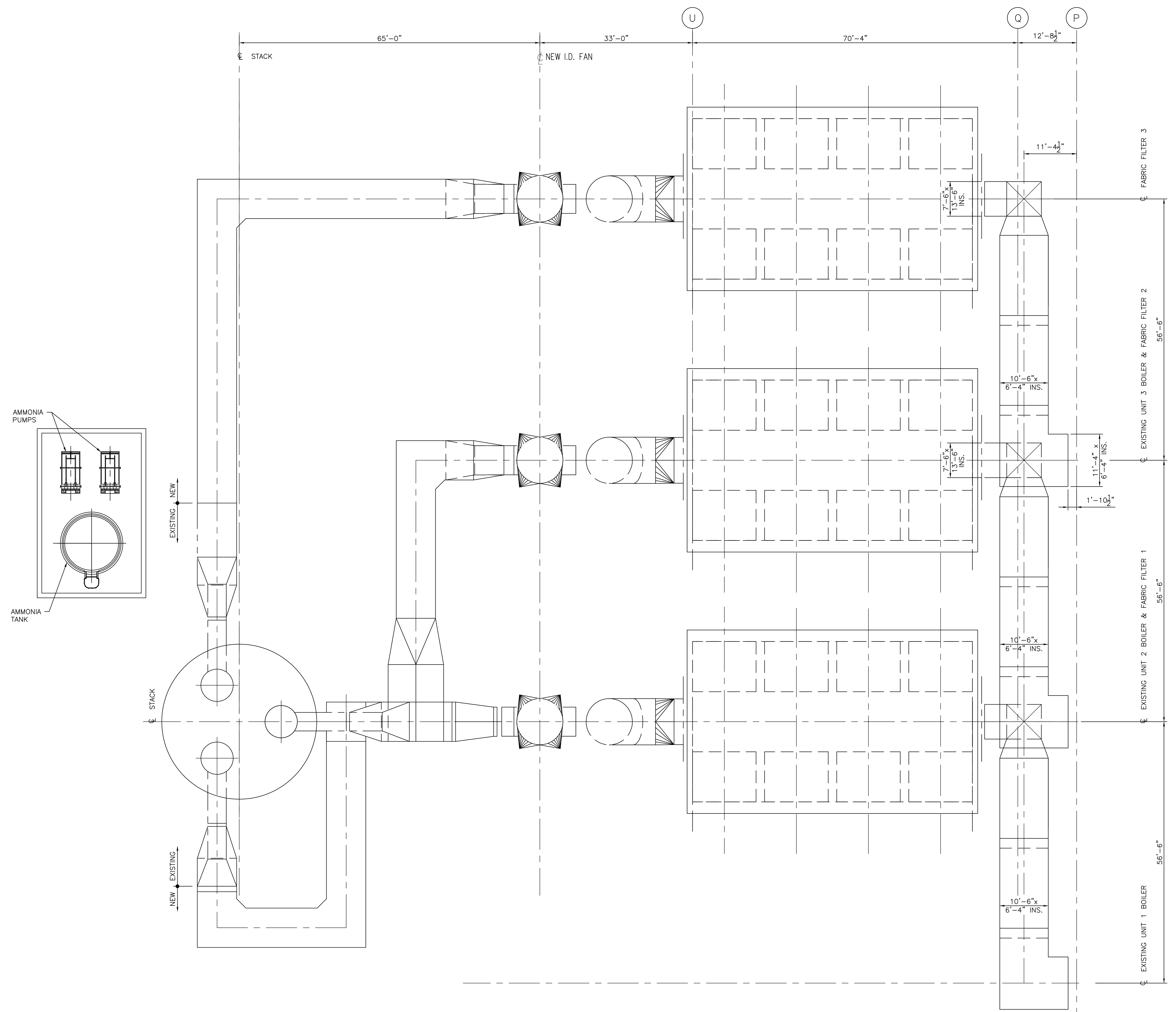
**BABCOCK POWER ENVIRONMENTAL INC.**

PROPOSED RSCR – FABRIC FILTER ADDITION
PLAN VIEW A–A

WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750121
REV. NO. P0

DWG. NO. 100825–0926750122




PLAN SECTION B–B
(120–E,2)

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THIRD ANGLE PROJECTION

DO NOT SCALE
USE DIMENSIONS ONLY

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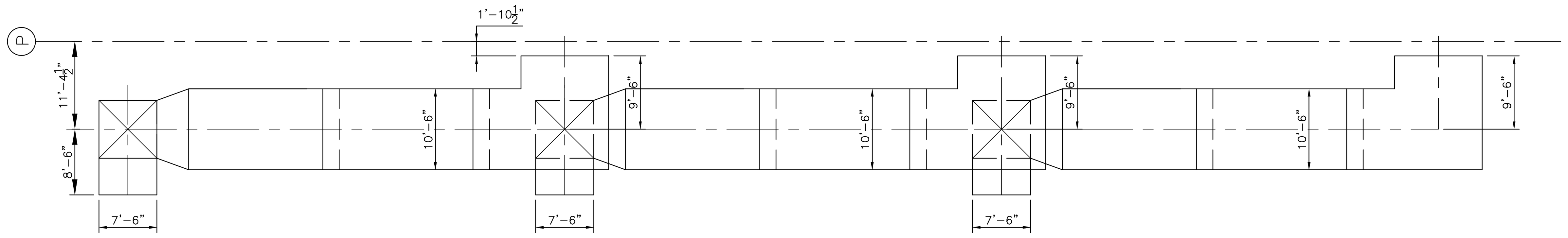
**BABCOCK POWER ENVIRONMENTAL INC.**

PROPOSED RSCR – FABRIC FILTER ADDITION
PLAN SECTION B–B

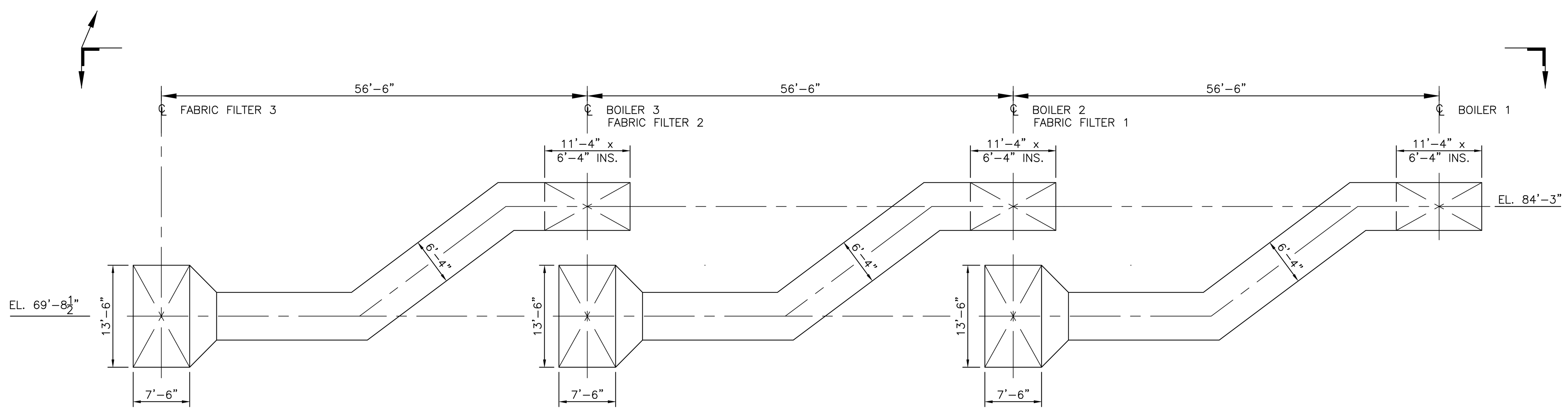
WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750122
REV. NO. P0

DWG. NO. 100825–0926750123




PLAN VIEW




VIEW C–C
(120–E,8)

PRELIMINARY
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THIRD ANGLE PROJECTION

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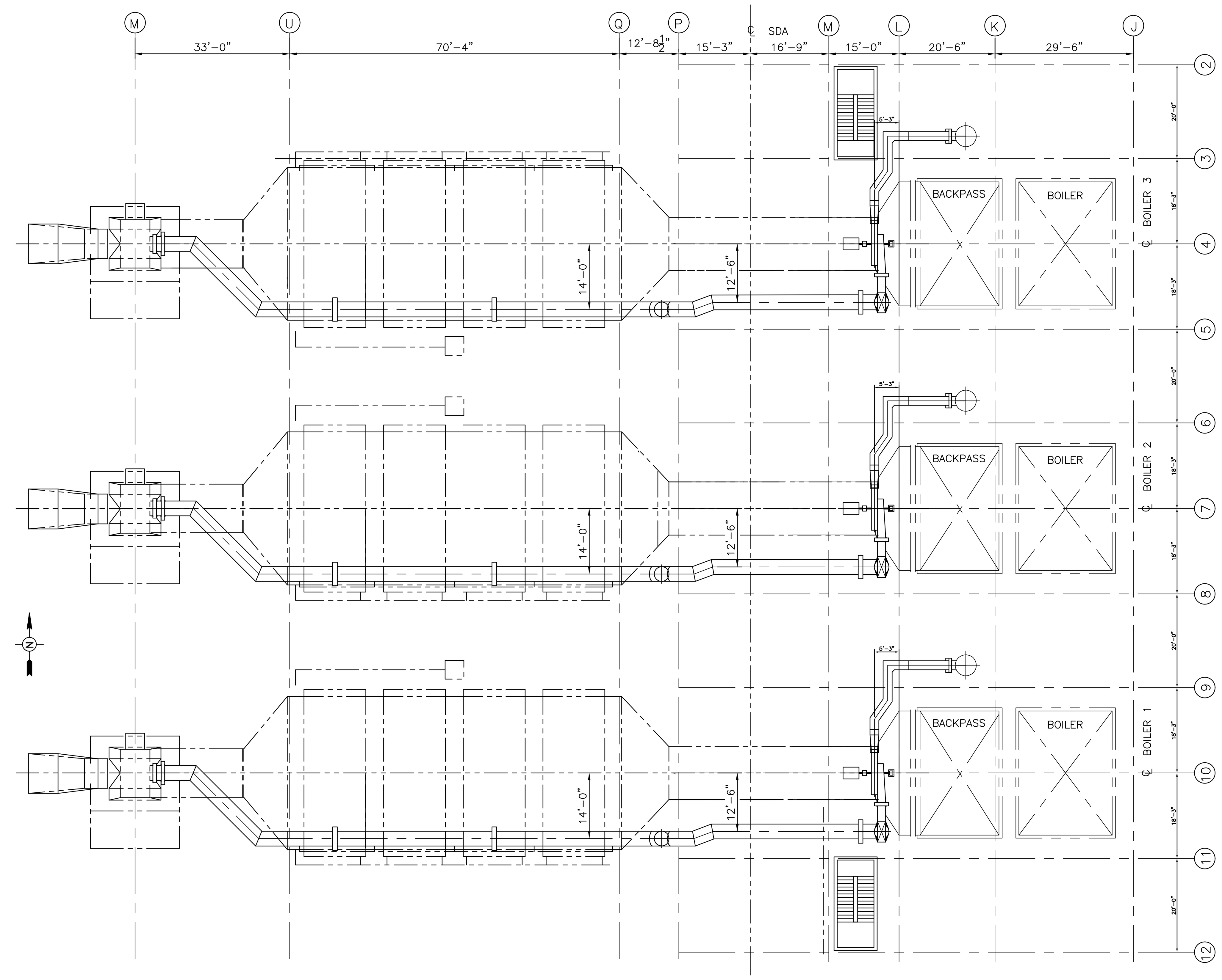
**BABCOCK POWER ENVIRONMENTAL INC.**

PROPOSED RSCR – FABRIC FILTER ADDITION
ELEVATION VIEW C–C

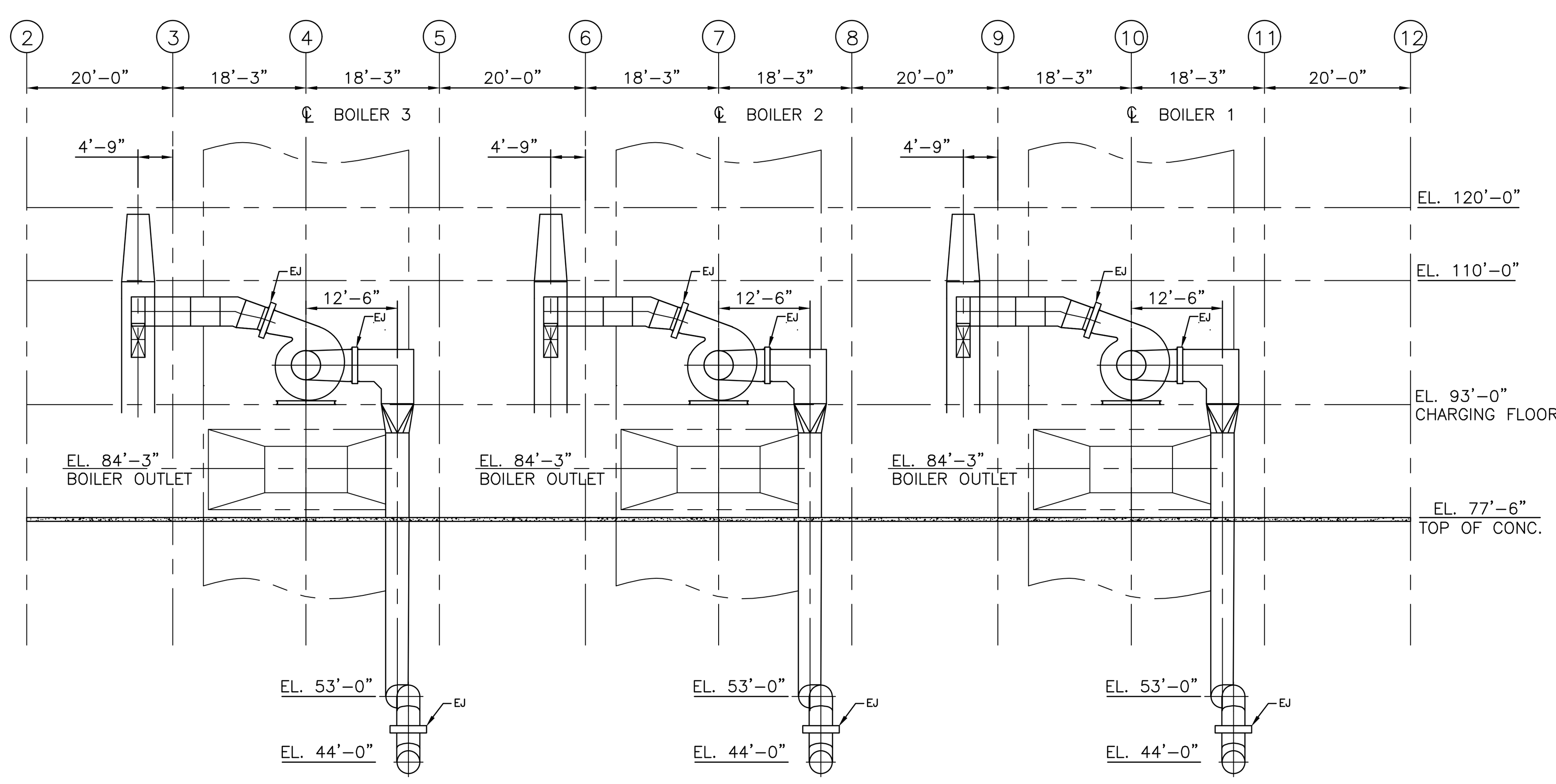
WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750123
REV. NO. P0

DWG. NO. 100825–0926750130

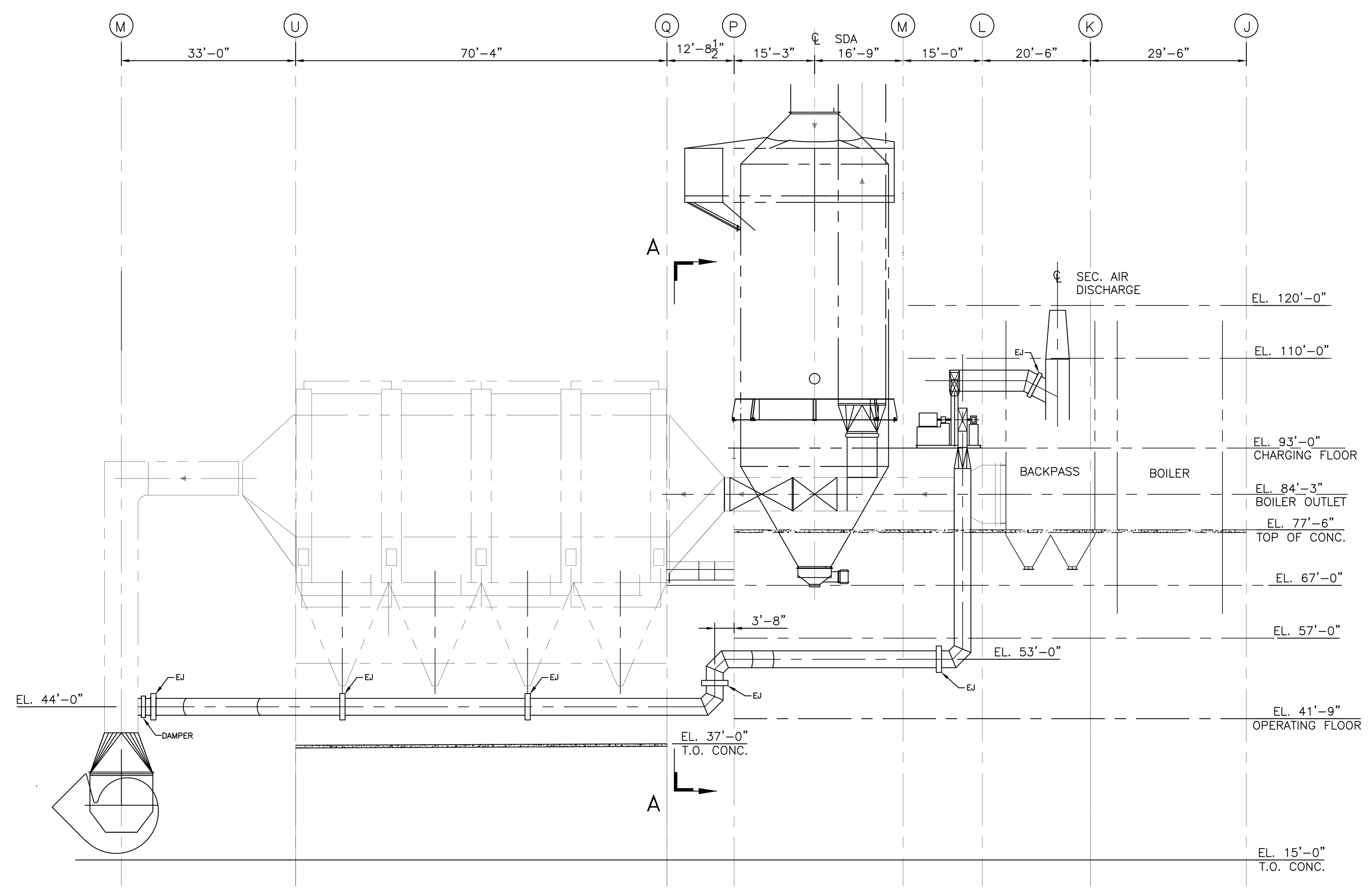



PLAN VIEW




SECTION A–A

ELEVATION VIEW
LOOKING EAST




ELEVATION LOOKING NORTH

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THIRD ANGLE PROJECTION

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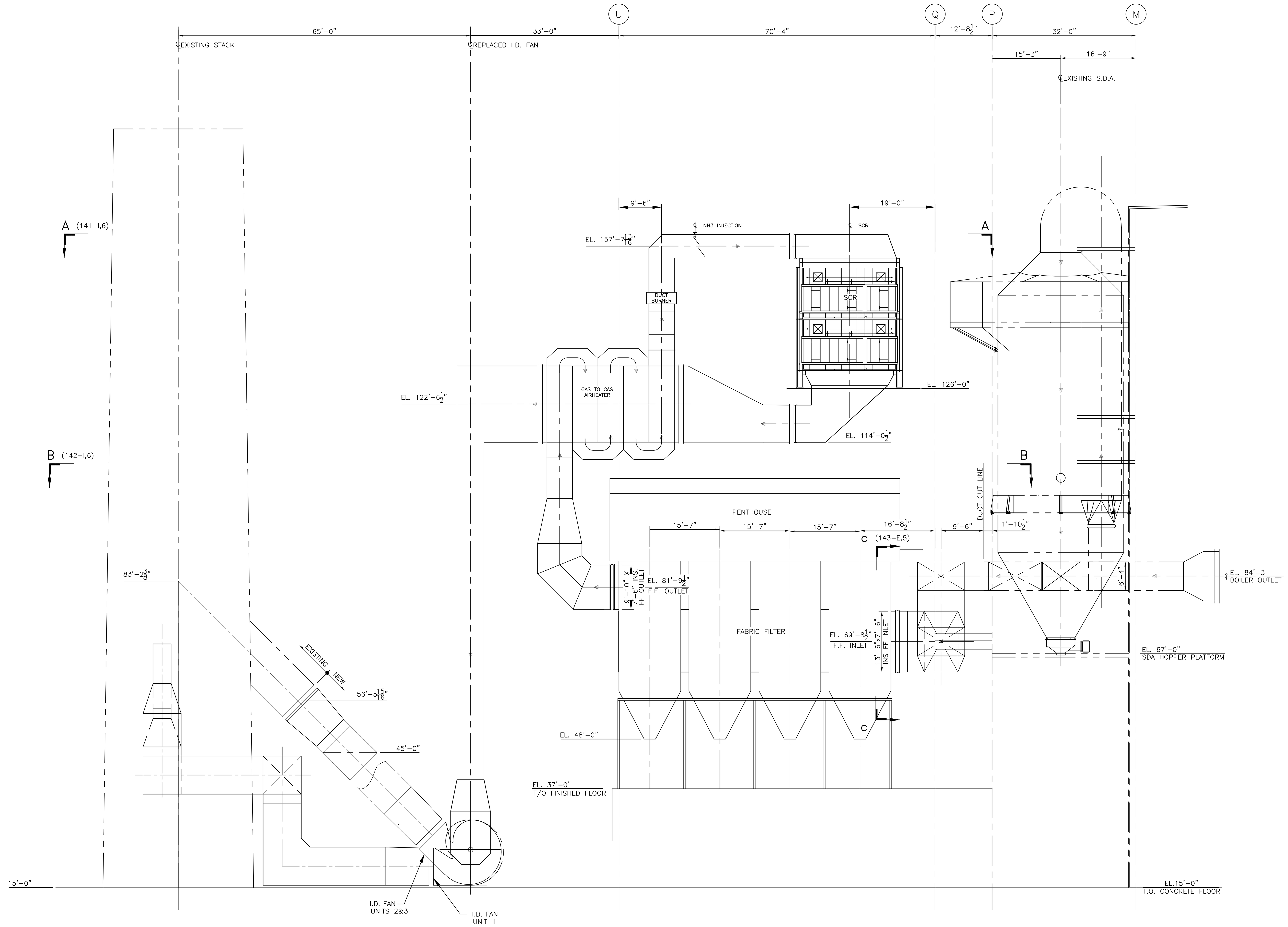
**BABCOCK POWER ENVIRONMENTAL INC.**

PROPOSED FLUE GAS RECIRCULATION ADDITION

WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750130 REV. NO. P1

DWG. NO. 100825–0926750140




ELEVATION VIEW
PLANT VIEW NORTH

PRELIMINARY
7/15/19

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THIRD ANGLE PROJECTION

DO NOT SCALE
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SCALE 3/32 IN. = 1 FT.

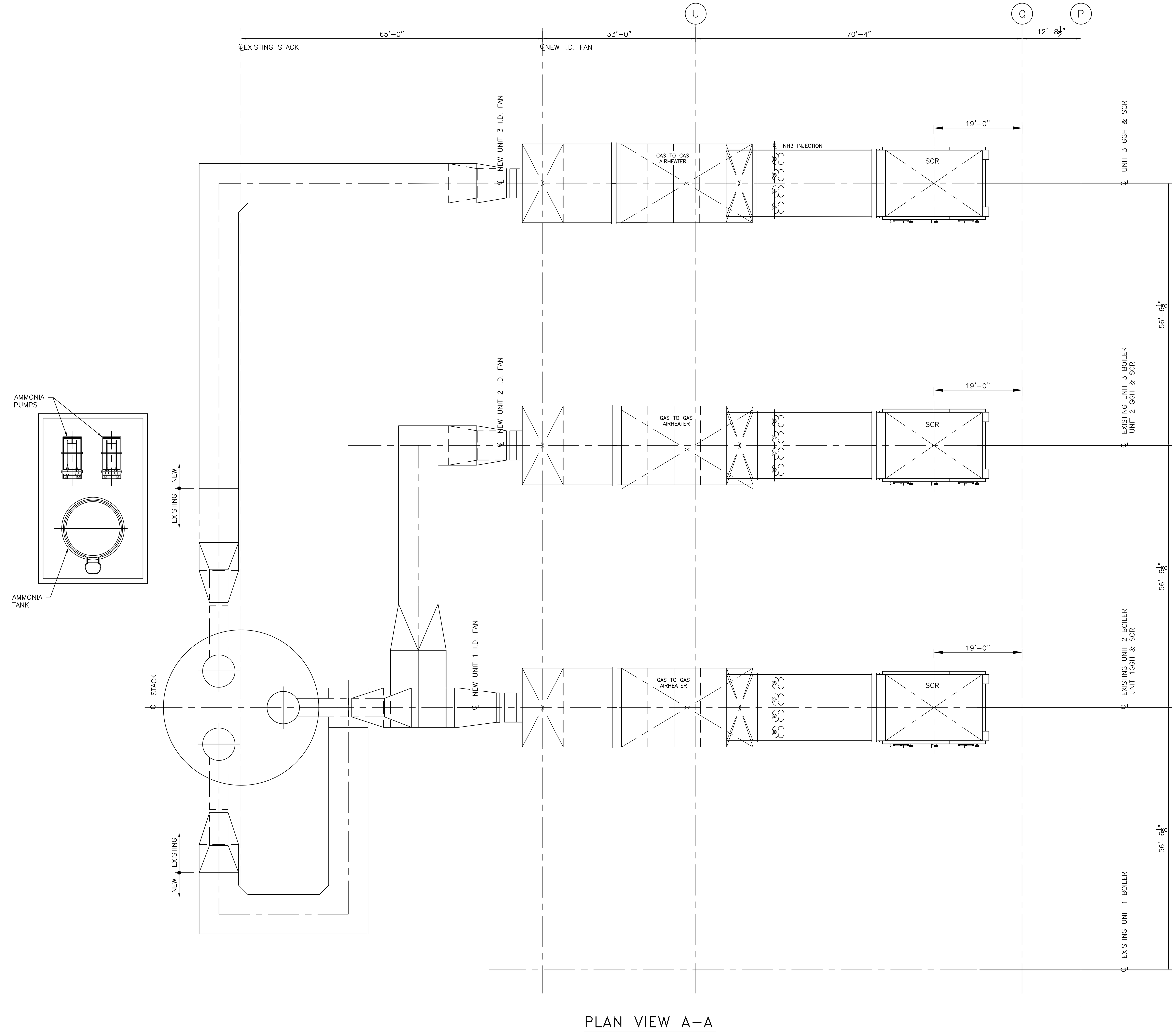
**BABCOCK POWER ENVIRONMENTAL INC.**

SCR, AIRHEATER AND FABRIC FILTER ADDITION
ELEVATION VIEW LOOKING NORTH

WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750140
REV. NO. P0

DWG. NO. 100825-0926750141




PLAN VIEW A-A
(140-C,2)

PRELIMINARY
7/15/19

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THIS DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS IT CONTAINS DATE AND SIGNATURE OF APPROVAL AND THE COMPANY RESERVES THE RIGHT TO CORRECT ANY ERRORS OR OMISSIONS PRIOR TO ACTUAL START OF WORK.

RELEASED & APPROVED
DATE

THIRD ANGLE PROJECTION

DO NOT SCALE
USE DIMENSIONS ONLY

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DRAWN A. Crowley
DATE 07/15/19
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SCALE 3/32 IN. = 1 FT.

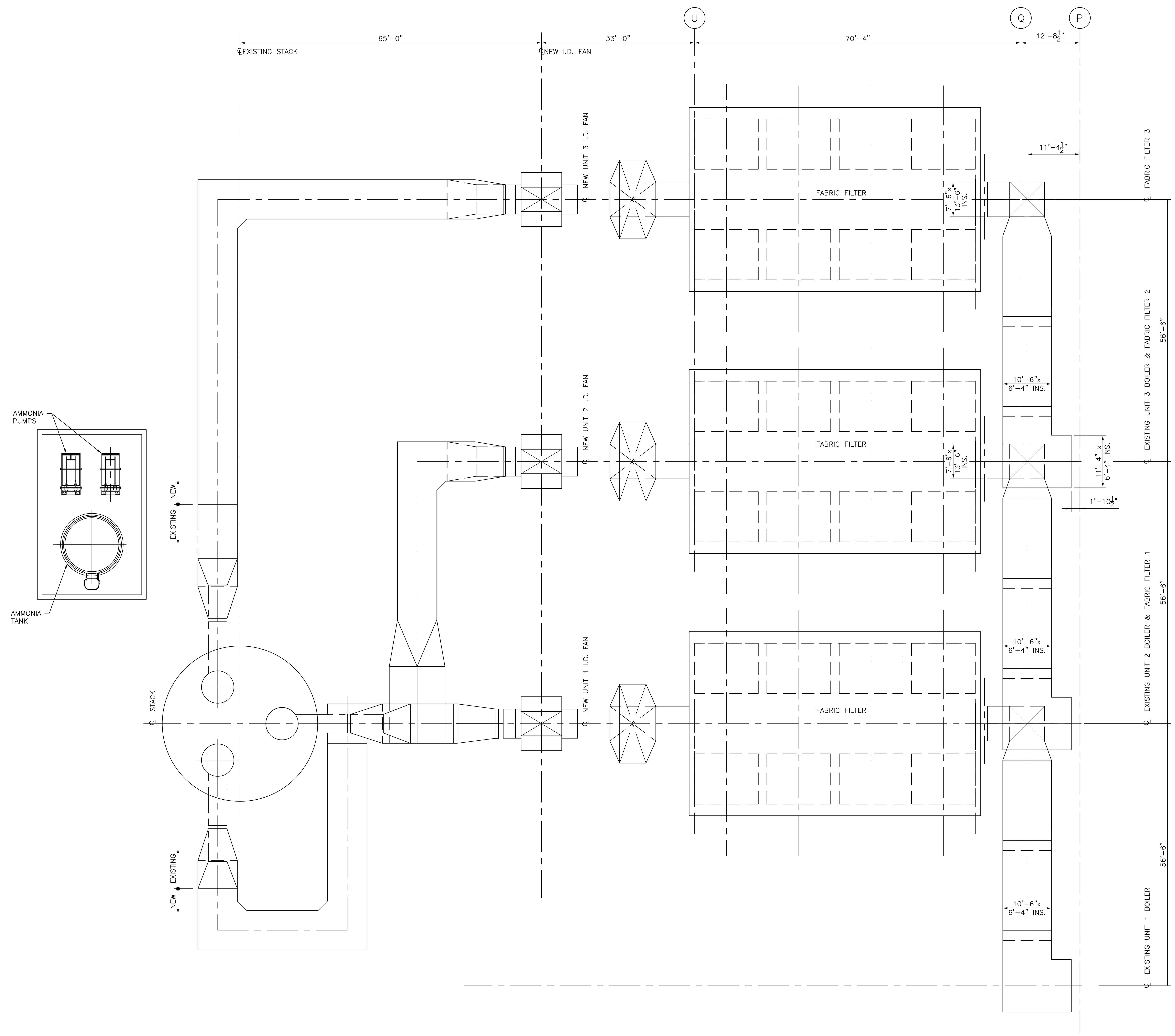
**BABCOCK POWER ENVIRONMENTAL INC.**

SCR, AIRHEATER AND FABRIC FILTER ADDITION
PLAN VIEW A-A

WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825-0926750141
REV. NO. P0

DWG. NO. 100825-0926750142




PLAN SECTION B-B
(140-E,2)

PRELIMINARY
7/15/19

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THIS DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS IT CONTAINS DATE AND SIGNATURE OF APPROVAL AND THE COMPANY RESERVES THE RIGHT TO CORRECT ANY ERRORS OR OMISSIONS PRIOR TO ACTUAL START OF WORK.

RELEASED & APPROVED DATE

THIRD ANGLE PROJECTION

DO NOT SCALE
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SCALE 3/32 IN. = 1 FT.

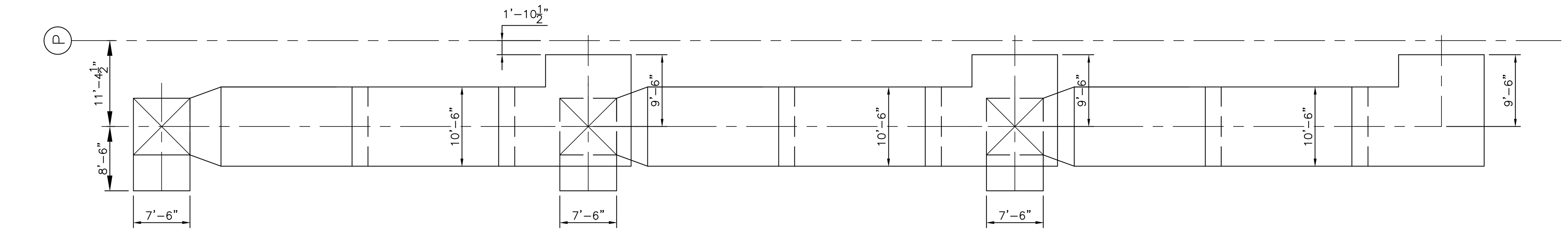
**BABCOCK POWER ENVIRONMENTAL INC.**

SCR, AIRHEATER AND FABRIC FILTER ADDITION
PLAN SECTION B-B

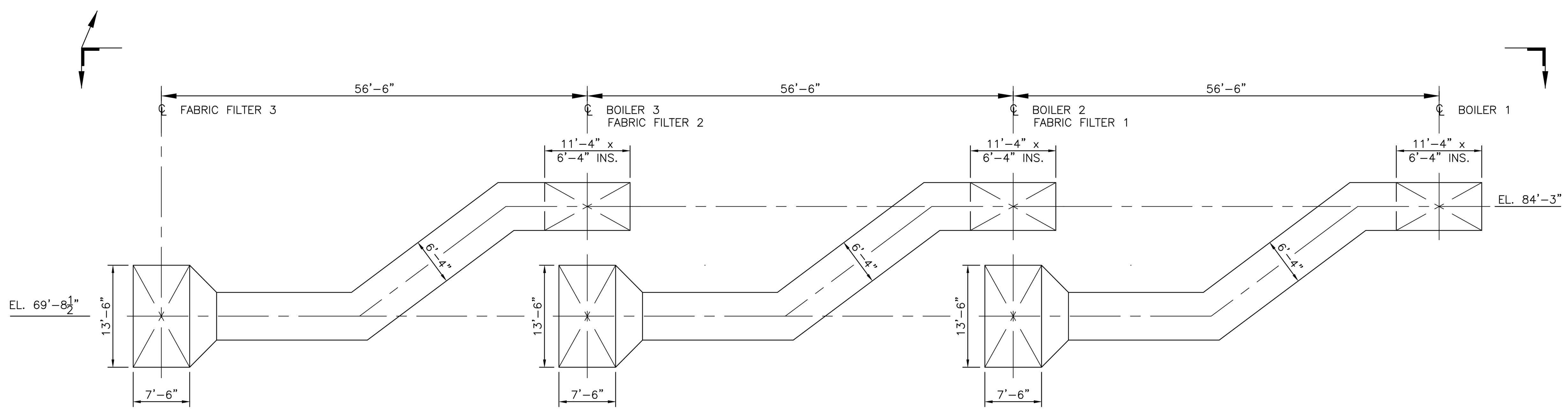
WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825-0926750142
REV. NO. P0

DWG. NO. 100825–0926750143




PLAN VIEW




VIEW C–C
(140–E,8)

PRELIMINARY
7/15/19

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RELEASED & APPROVED ______ DATE ______

THIRD ANGLE PROJECTION

DO NOT SCALE
USE DIMENSIONS ONLY

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SCALE 3/32 IN. = 1 FT.

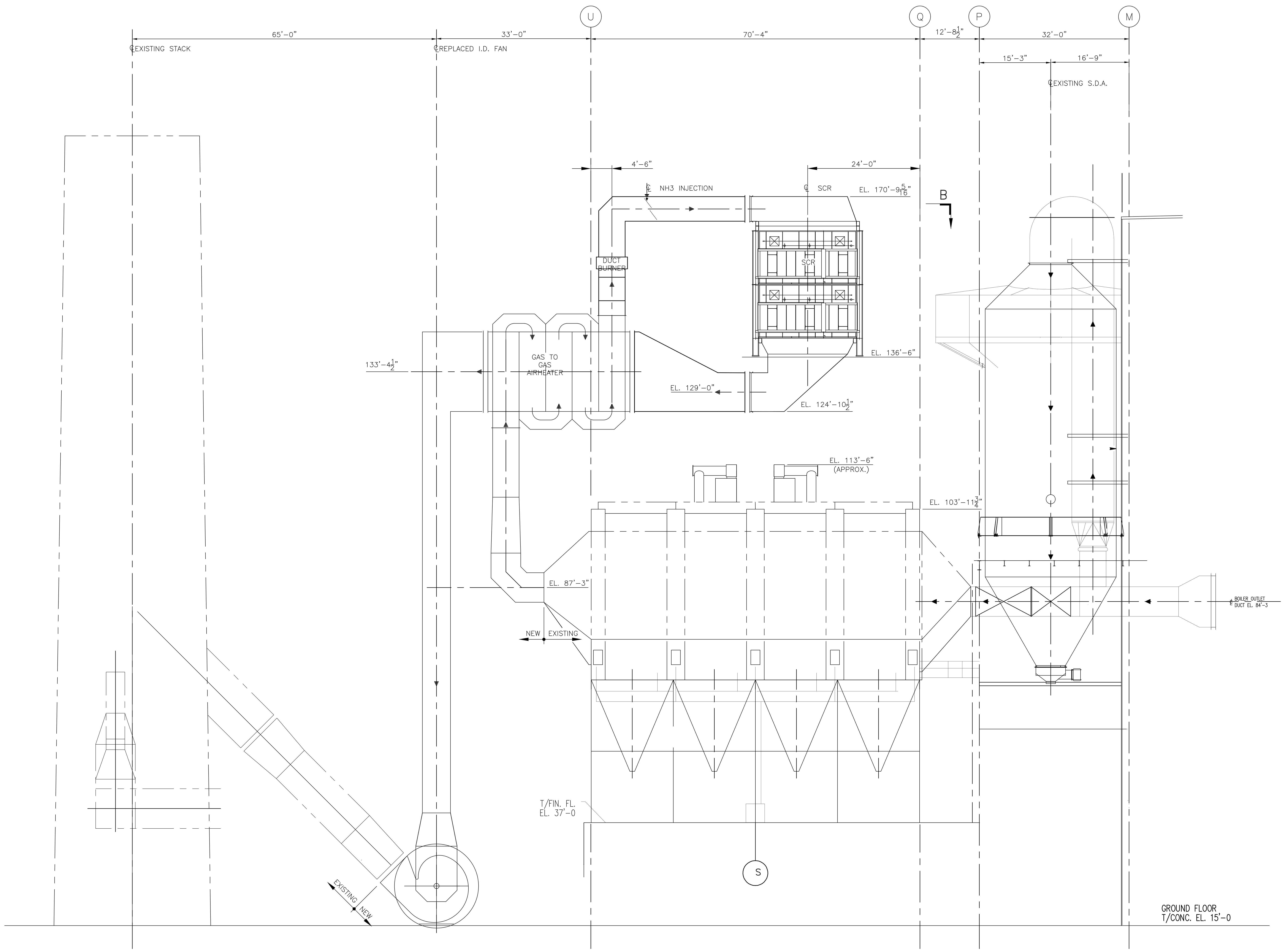
**BABCOCK POWER ENVIRONMENTAL INC.**

SCR, AIRHEATER AND FABRIC FILTER ADDITION
ELEVATION VIEW C–C

WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750143 REV. NO. P0

DWG. NO. 100825–0926750150




# SIDE ELEVATION

LOOKING PLANT NORTH

PRELIMINARY
11/5/19

| REVISION | NO. | BY | CHK | DATE | APP'D | DATE |
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| ADDED TR SETS. RAISED SCR & A.H. | P1 | AC | – | – | – | – |



THIS DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS IT CONTAINS DATE AND SIGNATURE OF APPROVAL AND THE COMPANY RESERVES THE RIGHT TO CORRECT ANY ERRORS OR OMISSIONS PRIOR TO ACTUAL START OF WORK.

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THIRD ANGLE PROJECTION

DO NOT SCALE
USE DIMENSIONS ONLY

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SCALE 3/32 IN. = 1 FT.

**BABCOCK POWER ENVIRONMENTAL INC.**

SCR & AIRHEATER ADDITION
ABOVE EXISTING PRECIPITATOR
ELEVATION VIEW LOOKING NORTH
WHEELABRATOR TECHNOLOGIES BALTIMORE
NOx FEASIBILITY STUDY
BALTIMORE, MARYLAND

DWG. NO. 100825–0926750150
REV. NO. P1

# APPENDIX C REFERENCE LISTS

Reference lists for catalyst vendors who have tail-end experience with MWCs are presented on the following pages.

## Waste Incineration

umicore

| Country | End User | Plant | Size | DeNOx | Catalyst | Start-Up Year |
|---|---|---|---|---|---|---|
| Belgium | Bruxelles Energie | Municipal Waste Plant - 3 lines | 200,000 $Nm^3/hr$ | 83% | DNX-930 | 2005 |
| China | Dow Corning | Chemical Waste Incinerator | 286,000 $Nm^3/hr$ | 93% | DNX-949 | 2013 |
| China | Qingdao Haiwan Chemical Co., Ldt. | Chemical Waste Incinerator | 37,400 $Nm^3/hr$ | 88% | DNX-939 | 2019 |
| China | Shandong New Synthesis Amino Acid | Waste Incineration | 13,400 $Nm^3/hr$ | 96% | DNX-LD3 | 2015 |
| China | Shandong Qingyuan | Waste Incineration | 22,500 $Nm^3/hr$ | 90% | DNX-LD4 | 2016 |
| China | Toure Shanghai | Hazardous Waste Incineration | 60,000 $Nm^3/hr$ | 90% | DNX-LD3 | 2017 |
| China | Urban Management Committee of Yiw | Waste Incineration Plant | 175,000 $Nm^3/hr$ | 67% | DNX LD-939 | 2018 |
| China | Wanhua Chemical Group Co., Ldt | Wanhua Yantai IPN Incinerator | 39,800 $Nm^3/hr$ | 99% | DNX LD-949 | 2019 |
| China | Zhejiang Feida Sci. and Tech. Co. Ldt. | Feixi Waste Incineration Units | --- | 50% | DNX LD-939 | 2020 |
| China | Xian Tao Waste Incineration | Units 1-2 | 152,000 $Nm^3/hr$ | 60% | LD-939 | 2018 |
| Czech Republic | Palivony Kombinat | Off-gas Incinerator (SNOX) | 54,000 $Nm^3/hr$ | 95% | DNX-932 | 1993 |
| Denmark | Amager Resourcecenter | Municipal Waste Plant - 2 lines | 267,000 $Nm^3/hr$ | 95% | DNX-LD5 | 2016 |
| Finland | Lahti Energia OY | Kymijarvi Unit 2 | 221,000 $Nm^3/hr$ | 90% | DNX-939 | 2011 |
| France | Idex Fassa Envinronment | Dinan Units 1-2 | 46,100 $Nm^3/hr$ | 77% | DNX-939 | 2012 |
| France | Siom de la Valee Chevreuse | Incineration Plant Line 1 | 90,000 $Nm^3/hr$ | 70% | DNX-939 | 2008 |
| France | Siom de la Valee Chevreuse | Incineration Plant Line 2 | 54,000 $Nm^3/hr$ | 77% | DNX-930 | 2007 |
| France | Sitom 19 | Brive Incineration Plant | 51,000 $Nm^3/hr$ | 47% | DNX-LD4 | 2014 |
| France | SVDU | Usine d'Incineration, Cve de S | 31,000 $Nm^3/hr$ | 60% | DNX-959 | 2017 |
| France | Syvedac, Sirac | Incineration Plant - 2 Lines | 60,700 $Nm^3/hr$ | 50% | DNX-940 | 2005 |
| Ireland | Eli Lilly | Incinerator | 10,000 $Nm^3/hr$ | 78% | DNX-930 | 2006 |
| Italy | Accam SpA | Incineration Plant | 67,000 $Nm^3/hr$ | 67% | DNX LD-939 | 2018 |
| Italy | AEM Gestioni | Incineration Plant | 42,000 $Nm^3/hr$ | 79% | DNX-LD3 | 2015 |
| Italy | Alto Vincente Ambiente | Incineration Plant - Line 2 | 34,000 $Nm^3/hr$ | 86% | DNX-939 | 2011 |
| Italy | Alto Vincente Ambiente | Incineration Plant - Line 3 | 49,300 $Nm^3/hr$ | 86% | DNX-939 | 2011 |
| Italy | Alto Vincente Ambiente | Incineration Plant | 32,000 $Nm^3/hr$ | 93% | DNX-LD3 | 2015 |
| Italy | Brianza Energia Ambiente | Incineration Plant - 2 Lines | 49,000 $Nm^3/hr$ | 70% | DNX-LD3 | 2016 |
| Italy | Core | Incineration Plant - Units A-C | 25,000 $Nm^3/hr$ | 59% | DNX-959 | 2010 |
| Italy | Provincia Autonoma di Bolzano | Incineration Plant | 117,000 $Nm^3/hr$ | 85% | DNX-930 | 1996 |
| Italy | REA Rifuti Energia Embiente | Incineration Plant - Line A+B | 68,000 $Nm^3/hr$ | 94% | DNX-930 | 2007 |
| Italy | Undisclosed, (Area Impianti) | Waste Incineration, 2 Lines | 84,300 $Nm^3/hr$ | | DNX-939 | 2012 |
| Libya | SIPSA Engineering | Chem. Weapon Destruction | 5,400 $Nm^3/hr$ | 50% | DNX-949 | 2011 |
| Middle East | Undisclosed client | One Unit | 34,700 $Nm^3/hr$ | 80% | DNX-920 | 2005 |
| Romania | SNP Petrochem S.A. Arpechim | Gas Incineration | 140,000 $Nm^3/hr$ | 99% | DNX-940 | 2004 |
| Saudi Arabia | Sadara Chemical Company | Waste Gas Incineration, Units | 147,000 $Nm^3/hr$ | 43% | DNX-949 | 2015 |
| Spain | Union Wuimico Farmaceutica, A.A., Uq | Pharmaceutical Plant | 9,000 $Nm^3/hr$ | 90% | DNX-950 | 1998 |
| Thailand | Asahi Kasei | Industrial Waste Incineration | 591,000 $Nm^3/hr$ | 98% | DNX-949 | 2011 |
| Thailand | Ministry of Industrial Works | Waste Incinerator | 45 tons/day | 90% | DNX-930 | 2004 |
| The Netherlands | AVR Afvalverwerking | Incineration Plant | 70,000 $Nm^3/hr$ | 92% | DNX-929 | 2009 |
| The Netherlands | BMC, Moerdijk | Chicken Manure Incineration | 240,000 $Nm^3/hr$ | 71% | DNX-939 | 2012 |
| The Netherlands | ESKA Graphic Board B.V. | Hoogezand Paper Mill | 21,700 $Nm^3/hr$ | 86% | DNX-LD3 | 2016 |
| The Netherlands | Lyondell Basell | Waste Incinerator | 156,000 $Nm^3/hr$ | 88% | DNX LD-939 | 2019 |
| The Netherlands | SITA ReEnergy | Incineration Plant | 67,000 $Nm^3/hr$ | 80% | DNX-949 | 2007 |
| UK | Suez | Suez Eco Park Surrey | 40,800 $Nm^3/hr$ | 48% | DNX HD-864 | 2019 |
| USA | Clean Harbors | Eldorao, Arkansas Facility | 103,000 $Nm^3/hr$ | 95% | DNX LD-939 | 2018 |
| USA | Clean Harbors | Incinerator Haz. Waste | 103,000 $Nm^3/hr$ | 95% | DNX LD-939 | 2015 |
| USA | OxyVinyls | Incinerator - 2 Units | 36,000 $Nm^3/hr$ | | DNX-930 | 2002 |
| USA | OxyMar | Incinerator - 2 Units | 36,000 $Nm^3/hr$ | | DNX-930 | 2002 |
| USA | White Mountain Energy | SOG Incinerator | 87,000 $Nm^3/hr$ | 86% | DNX-958 | 2004 |

# Reference List
for Honeycomb Catalyst
as of August 2018

| Curr.No. | Project | Client | End user / Engineering company | Plant location | Application | Shipped quantity | Delivery date |
|---|---|---|---|---|---|---|---|
| 1. | **MVA Spittelau** | SGP | Heizbetriebe Wien | AUT | Municipal Waste, Tail End | 39 m³ | 1989 |
| 2. | **Ceilcote** | SGP | MGC Plasma AG | CHE | Hazardous Waste | 2 m³ | 1990 |
| 3. | **MVA Heidelberg** | SGP | UNI-Bauamt Heidelberg | DEU | Hospital Waste, Low Temp. | 3 m³ | 1990 |
| 4. | **MVA Spittelau Dioxin** | SGP | Heizbetriebe Wien | AUT | Municipal Waste, Tail End | 22 m³ | 1991 |
| 5. | **Knoll** | SGP | | CHE | Waste, High Dust | 2 m³ | 1992 |
| 6. | **MVA Flötzersteig** | AEE | Heizbetriebe Wien | AUT | Municipal Waste, Tail End | 52 m³ | 1992 |
| 7. | **MVA Burgkirchen** | SHL | ZAS | DEU | Waste, Tail End | 24 m³ | 1993 |
| 8. | **München Nord** | BASF | Stadtwerke München | DEU | Waste, Tail End | 49 m³ | 1993 |
| 9. | **MVA Rotterdam** | SGP | AVR | NLD | Municipal Waste, Low Temp. | 321 m³ | 1993 / 95 |
| 10. | **Bayer Dormagen** | BASF | Lentjes | DEU | Hazardous Waste, Tail End | 32 m³ | 1994 |
| 11. | **MVA Schwandorf** | BASF | Lentjes | DEU | Municipal Waste | 130 m³ | 1994 |
| 12. | **Nijmegen** | BASF | KRC | NLD | Municipal Waste, Tail End | 35 m³ | 1994 |
| 13. | **MVA Mannheim K1-3** | BASF | EVT | DEU | Municipal Waste, Tail End | 86 m³ | 1994 |
| 14. | **MVA Essen Karnap** | BASF | EVT | DEU | Municipal Waste, Tail End | 140 m³ | 1994 |
| 15. | **ZVSMM Schwabach** | BASF | Lurgi | DEU | Chemical Waste | 9 m³ | 1994 |
| 16. | **RSMV Ciba Geigy** | BASF | Ciba Geigy | CHE | Hazardous Waste | 12 m³ | 1995 |
| 17. | **BASF Residue Incin. N800** | BASF | BASF | DEU | Hazardous Waste, Low Dust | 233 m³ | 1995 |
| 18. | **MVA Wels** | AEE | WAV | AUT | Municipal Waste, Tail End | 20 m³ | 1995 |
| 19. | **MVA Leudelingen** | BASF | | LUX | Municipal Waste, Tail End | 16 m³ | 1995 |
| 20. | **MHKW Darmstadt** | BASF | | DEU | Municipal Waste | 100 m³ | 1995 |
| 21. | **Wuppertal** | BASF | | DEU | Municipal Waste, Low Temp. | 154 m³ | 1995 |
| 22. | **Bayer Bürrig** | BASF | Bayer AG | DEU | Chemical Waste | 43 m³ | 1995 |
| 23. | **Bayer Uerdingen** | BASF | Bayer AG | DEU | Chemical Waste | 12 m³ | 1995 |
| 24. | **SYSAV** | BASF | Sysav | SWE | Municipal Waste | 11 m³ | 1995 |
| 25. | **ROW Wesseling** | BASF | ROW | DEU | Waste | 24 m³ | 1995 |
| 26. | **Schwarzheide** | BASF | Integral | DEU | Hazardous Waste, Tail End | 29 m³ | 1995 |
| 27. | **MVA Iserlohn** | BASF | | DEU | Municipal Waste | 87 m³ | 1995 |

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|---|---|---|---|---|---|---|---|
| 28. | **SMVA Lonza** | AEE | Lonza AG | CHE | Residue, Tail End | 25 m³ | 1995 |
| 29. | **KVA Thurgau** | AEE | Verband KVA Thurgau | CHE | Municipal and Industrial Waste, Tail End | 33 m³ | 1996 |
| 30. | **MVA Bielefeld** | BASF | | DEU | Municipal Waste | 204 m³ | 1996 |
| 31. | **CZ Süd** | BASF | BASF | DEU | Residue, Tail End | 3 m³ | 1996 |
| 32. | **Höchst** | BASF | Hoechst AG | DEU | Hazardous Waste | 21 m³ | 1996 |
| 33. | **KVA St. Gallen** | BASF | AEE | CHE | Municipal Waste, Tail End | 11 m³ | 1996 |
| 34. | **MHKW Ludwigshafen** | BASF | | DEU | Municipal Waste | 78 m³ | 1996 |
| 35. | **MVA Flingern** | BASF | | DEU | Municipal Waste, Tail End | 106 m³ | 1996 |
| 36. | **MHKW Bamberg** | BASF | | DEU | Municipal Waste | 21 m³ | 1996 |
| 37. | **HKW München Nord** | BASF | | DEU | Municipal Waste | 63 m³ | 1996 |
| 38. | **MKW Weissenhorn** | BASF | | DEU | Municipal Waste | 41 m³ | 1996 |
| 39. | **MVA Zavin** | AEE | | NLD | Hospital Waste, Low Temp. | 7 m³ | 1996 |
| 40. | **Colombes** | Integral | | FRA | Waste, Tail End | 20 m³ | 1996 |
| 41. | **CIBA Geigy** | Smogless | | ITA | Waste | 6 m³ | 1997 |
| 42. | **MVA Mannheim IV** | BASF | | DEU | Municipal Waste, Tail End | 46 m³ | 1997 |
| 43. | **MVA Zagreb** | Hafner | | HRV | Waste | 4 m³ | 1997 |
| 44. | **GMVA Niederrhein** | BASF | | DEU | Municipal Waste | 58 m³ | 1997 |
| 45. | **RMVA Köln** | BASF | | DEU | Municipal Waste | 115 m³ | 1997 |
| 46. | **MVA Lenzing** | Integral | | AUT | Waste, Tail End | 29 m³ | 1997 |
| 47. | **BASF N806** | BASF | BASF | DEU | Hazardous Waste, Low Dust | 24 m³ | 1997 |
| 48. | **MVA Constanti** | BASF | AE-Energietechnik | ESP | Hazardous Waste, Low Dust | 29 m³ | 1998 |
| 49. | **MVA Wuppertal** | Integral | | DEU | Municipal Waste, Low Temp., Additional Delivery | 51 m³ | 1998 |
| 50. | **KVA Basel** | BASF | | CHE | Municipal Waste, Low Dust | 58 m³ | 1998 |
| 51. | **MVA Würzburg** | BASF | | DEU | Municipal Waste, High Dust | 16 m³ | 1998 |
| 52. | **MVA Buchs** | BASF | AE | CHE | Municipal Waste, Tail End | 54 m³ | 1998 |
| 53. | **SMVA Ostrava** | AE-Energietechnik | | CZE | Hazardous Waste, Tail End | 9 m³ | 1999 |
| 54. | **BASF N806** | BASF | BASF | DEU | Hazardous Waste, Low Dust | 8 m³ | 1999 |

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|---|---|---|---|---|---|---|---|
| 55. | **MVA Niederurnen** | BASF | | CHE | Municipal Waste | 57 m³ | 1999 |
| 56. | **Thermoselect Karlsruhe** | BASF | Steuler | DEU | Waste | 9 m³ | 1999 |
| 57. | **TRV-Wesseling** | BASF | | DEU | Industrial- and Hazardous Waste | 13 m³ | 1999 |
| 58. | **Genf Linie 5, 6, 3** | BASF | SIG / AE-Energietechnik | CHE | Municipal Waste, Low Dust | 139 m³ | 2000/01 |
| 59. | **Dalmine** | Integral | | ITA | Waste, Tail End | 13 m³ | 2000 |
| 60. | **Rhodia** | BASF | Rhodia | DEU | Hazardous/Liquide Waste | 14 m³ | 2000 |
| 61. | **BASF N810** | BASF | BASF | DEU | Hazardous Waste, Low Dust, Additional Delivery | 29 m³ | 2001 |
| 62. | **ROW-Wesseling TRV** | BASF | ROW | DEU | Industrial- and Hazardous Waste, Additional Delivery | 13 m³ | 2001 |
| 63. | **MVA Fribourg** | BASF | | CHE | Waste, Tail End | 33 m³ | 2001 |
| 64. | **Creteil** | BASF | ELEX | FRA | Municipal Waste, Tail End | 48 m³ | 2001 |
| 65. | **HIMTEC** | BASF | | ITA | Industrial Waste, Tail End | 5 m³ | 2001 |
| 66. | **CO-Catalyst Rotterdam** | AE-Energietechnik | AVR | NLD | Municipal Waste, Tail End, CO Oxidation | 6 m³ | 2001 |
| 67. | **MVA Bamberg** | BASF | | DEU | Municipal Waste, Tail End | 7 m³ | 2001 |
| 68. | **MVA Zavin** | BASF | Steuler | NLD | Hospital Waste, Low Temperature, Additional Delivery | 3 m³ | 2001 |
| 69. | **Thermoselect Karlsruhe** | BASF | EnBW | DEU | Waste | 7 m³ | 2001 |
| 70. | **MVA Würzburg** | BASF | BBP Environment | DEU | Municipal Waste, High Dust | 34 m³ | 2002 |
| 71. | **TRV Wesseling** | BASF | | DEU | Industrial- and Hazardous Waste, Additional Delivery | 13 m³ | 2002 |
| 72. | **Halmstads Renhallnings AB** | BASF | BBP Environment | SWE | Municipal Waste, Tail End | 19 m³ | 2002 |
| 73. | **Bayer Antwerpen** | BASF | Bayer AG | BEL | Industrial Waste, Tail End | 13 m³ | 2002 |
| 74. | **KVA Turgi** | BASF | GV Region Baden-Brugg | CHE | Municipal Waste, Tail End | 11 m³ | 2002 |
| 75. | **GMVA Oberhausen** | BASF | | DEU | Municipal Waste, Tail End | 19 m³ | 2002 |
| 76. | **MVA Malmö** | BASF | LAB | SWE | Municipal Waste, Tail End | 30 m³ | 2002 |
| 77. | **KVA Thurgau** | BASF | CTU | CHE | Municipal Waste, Tail End, Additional Delivery | 8 m³ | 2002 |
| 78. | **Nijmegen** | BASF | | NLD | Municipal Waste, Tail End, Additional Delivery | 6 m³ | 2002 |
| 79. | **Genf Linie 5** | BASF | CTU | CHE | Municipal Waste, Low Dust, Additional Delivery | 55 m³ | 2002 |
| 80. | **T.A. Lauta** | AE | STEAG | DEU | Municipal Waste, Tail End, Low Temp. | 47 m³ | 2003 |
| 81. | **RSMVA Basel** | BASF | Valorec Services AG | CHE | Residue, Additional Delivery | 12 m³ | 2003 |

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|---|---|---|---|---|---|---|---|
| 82. | **EBS WSO 4** | Integral | Fernwärme Wien | AUT | Sludge, Municipal Waste | 22 m³ | 2003 |
| 83. | **Nimes** | Integral | | FRA | Waste, Tail End | 9 m³ | 2003 |
| 84. | **Le Havre** | Integral | | FRA | Waste, Tail End | 13 m³ | 2003 |
| 85. | **TRV Niklasdorf** | AEE | | AUT | Waste, Tail End | 12 m³ | 2003 |
| 86. | **Nijmegen Line 2** | BASF | | NLD | Municipal Waste, Tail End, Additional Delivery | 11 m³ | 2003 |
| 87. | **MVA Constanti** | BASF | | ESP | Hazardous Waste, Low Dust, Additional Delivery | 10 m³ | 2003 |
| 88. | **KVA St. Gallen** | BASF | | CHE | Municipal Waste, Tail End, Additional Delivery | 9 m³ | 2003 |
| 89. | **TBA Arnoldstein** | AEE | KRV | AUT | Municipal Waste, Tail End, Low Temp. | 14 m³ | 2003 |
| 90. | **DOMO Caproleuna** | BASF | | DEU | Residue, Tail End | 3 m³ | 2003 |
| 91. | **Höchst** | BASF | Höchst | DEU | Hazardous Waste, Additional Delivery | 11 m³ | 2003 |
| 92. | **TRV Wesseling** | BASF | | DEU | Industrial- and Hazardous Waste, Additional Delivery | 13 m³ | 2004 |
| 93. | **Colleferro Unit 1 & 2** | | Termokimik | ITA | Municipal Waste, Tail End | 36 m³ | 2004 |
| 94. | **Genf Linie 6** | BASF | SIG / CTU | CHE | Municipal Waste, Low Dust, Additional Delivery | 72 m³ | 2004 |
| 95. | **ICDI Charleroi** | HRC | | BEL | Municipal Waste, Low Dust | 7 m³ | 2004 |
| 96. | **KVA Basel** | BASF | | CHE | Municipal Waste, Low Dust | 29 m³ | 2004 |
| 97. | **WAV II Wels** | LAB GmbH | Energie AG Oberösterreich | AUT | Municipal Waste, Tail End | 41 m³ | 2005 |
| 98. | **Sammel SCR Simmering** | Envirgy | Fernwärme Wien | AUT | Sludge, Hazardous Waste, Tail End, Low Temp. | 125 m³ | 2005 |
| 99. | **Ostrava** | SPOVO | SPOVO | CZE | Hazardous Waste, Tail End, Low Temp. Additional Delivery | 3 m³ | 2005 |
| 100. | **Saint Ouen Unit 1-3** | BASF | LAB / SYCTOM | FRA | Municipal Waste, Tail End | 219 m³ | 2005 |
| 101. | **Brest** | | Termokimik | FRA | Municipal Waste, Tail End | 14 m³ | 2005 |
| 102. | **MSWI Bordeaux** | BASF | ASTRIA / HRC | FRA | Municipal Waste, Tail End | 85 m³ | 2005 |
| 103. | **CVDU Nice** | BASF | LAB | FRA | Municipal Waste, Tail End, Dioxin | 157 m³ | 2005 |
| 104. | **MVA Malmö** | BASF | LAB | SWE | Municipal Waste, Tail End, Additional Delivery | 22 m³ | 2005 |
| 105. | **Tirmadrid** | Integral | | ESP | Municipal Waste, Tail End, Low Temp. | 133 m³ | 2005 |
| 106. | **Rennes** | BASF | Von Roll | FRA | Municipal Waste, Tail End | 23 m³ | 2005 |
| 107. | **Nantes** | BASF | Von Roll | FRA | Municipal Waste, Tail End | 34 m³ | 2005 |
| 108. | **Coueron / Nantes** | BASF | LAB | FRA | Municipal Waste, Tail End | 12 m³ | 2005 |

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|---|---|---|---|---|---|---|---|
| 109. | **Recycling Komb. Rotterdam** | BASF | Steuler | NLD | Residue, Tail End | 13 m³ | 2005 |
| 110. | **BASF Incineration plant** | BASF | BASF | DEU | Residue, Raw gas, NOx- + CO-removal | 5 m³ | 2005 |
| 111. | **Chaumont** | HRC | SHMVD Chaumont | FRA | Municipal Waste, Tail End | 13 m³ | 2005 |
| 112. | **Constanti** | BASF | | ESP | Residue, Low Dust, Additional Delivery | 20 m³ | 2005 |
| 113. | **Kimhae** | BASF | SPECO | KOR | Municipal Waste, Tail End, Additional Delivery | 5 m³ | 2005 |
| 114. | **BASF CZ Süd** | BASF | BASF | DEU | Residue, Tail End, Additional Delivery | 3 m³ | 2005 |
| 115. | **Steuler** | BASF | Steuler | DEU | Waste, Tail End | 6 m³ | 2005 |
| 116. | **Sangju** | BASF | David Chemical | KOR | Waste, Tail End, Additional Delivery | 3 m³ | 2005 |
| 117. | **Genf Linie 5** | BASF | SIG | CHE | Municipal Waste, Low Dust, Additional Delivery | 72 m³ | 2006 |
| 118. | **MSW Ludres** | Hamon | Nancy Energie | FRA | Waste, Tail End, Low Temperature | 40 m³ | 2006 |
| 119. | **CENON** | Hamon | UIOM de Cenon | FRA | Municipal Waste, Tail End | 20 m³ | 2006 |
| 120. | **Rhodia** | BASF | Rhodia | DEU | Hazardous/Liquide Waste, Additional Delivery | 14 m³ | 2006 |
| 121. | **Kimhae** | BASF | SPECO | KOR | Municipal Waste, Tail End, Additional Delivery | 5 m³ | 2006 |
| 122. | **NANYA** | BASF | Lucky Lotus Corp. | TWN | Industrial Waste Additional Delivery | 2 m³ | 2006 |
| 123. | **Ferrara** | Alstom | Hera | ITA | Municipal Waste, Tail End, Low Temp. | 54 m³ | 2006 |
| 124. | **MVA Flötzersteig** | Integral | Fernwärme Wien | AUT | Municipal Waste, Tail End, Low Temp. | 71 m³ | 2006 |
| 125. | **MVA Pfaffenau** | Integral | WKU / Envirgy | AUT | Municipal Waste, Tail End, Low Temp. | 68 m³ | 2007 |
| 126. | **Dunkerque** | BASF | Dunkerque Grand Littoral / Von Roll | FRA | Municipal Waste, Tail End | 9 m³ | 2007 |
| 127. | **Issy-les-Moulineaux** | BASF | SYCTOM / Von Roll | FRA | Municipal Waste, Tail End, Low Temp. | 163 m³ | 2007 |
| 128. | **Forli** | Alstom | Hera | ITA | Municipal Waste, Tail End, Low Temp. | 44 m³ | 2007 |
| 129. | **BMC Moerdijk** | AEE | BMC Moerdijk BV | NLD | Chicken litter, Tail End | 20 m³ | 2007 |
| 130. | **AMSA Silla 2** | Termokimik | AMSA | ITA | Municipal Waste, Tail End, Low Temperature | 171 m³ | 2007 |
| 131. | **BASF CZ Süd II** | BASF | BASF | DEU | Residue Incineration | 4 m³ | 2007 |
| 132. | **MVA AVS 4825** | BASF | | DEU | Residue Incineration | 9 m³ | 2007 |
| 133. | **VA-Schottland** | BASF | LTB | DEU | Residue Incineration | 3 m³ | 2007 |
| 134. | **MVA Prag Linie 1-4 Prague-Malešice** | BASF | Pražske služby | CZE | Municipal Waste, Low Dust | 236 m³ | 2007 |
| 135. | **Constanti** | BASF | | ESP | Residue, Low Dust, Additional Delivery | 10 m³ | 2007 |

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|---|---|---|---|---|---|---|---|
| 136. | **Dadae MSWI** | SPECO | | KOR | Municipal Waste, Additional Delivery | 8 m³ | 2007 |
| 137. | **Myungji MSWi** | SPECO | | KOR | Municipal Waste, Additional Delivery | 25 m³ | 2007 |
| 138. | **Constanti** | BASF | Gestio De Residus Especials De Catalunya, S.A. | ESP | Residue, Low Dust, Additional Delivery | 10 m³ | 2007 |
| 139. | **MSW Antibes** | Hamon | Veolia | FRA | Municipal Waste, Tail End | 37 m³ | 2007 |
| 140. | **MVA Malmö** | BASF | LAB | SWE | Municipal Waste, Additional Delivery | 63 m³ | 2007 |
| 141. | **MVA Twence** | BASF | LAB | NLD | Municipal Waste, Tail End | 50 m³ | 2007 |
| 142. | **MVA Marseille** | BASF | LAB | FRA | Municipal Waste, Tail End | 29 m³ | 2007 |
| 143. | **Lamballe** | BASF | Marguin | FRA | Municipal Waste | 8 m³ | 2007 |
| 144. | **Icheon MSWI** | Dongbu | Dongbu | KOR | Municipal Waste | 16 m³ | 2007 |
| 145. | **Padova Line 2+3** | Termokimik | | ITA | Municipal Waste Low Temperature | 55 m³ | 2008/2009 |
| 146. | **Borsodchem NYRT** | BASF | Borsodchem ZRT | HUN | Municipal Waste, Tail End | 15 m³ | 2008 |
| 147. | **Rohdia Residue Boiler 5** | BASF | Rhodia | FRA | Residue Incineration | 96 m³ | 2008 |
| 148. | **Jeonggwan MSWI** | SPECO | SPECO | KOR | Municipal Waste | 6 m³ | 2008 |
| 149. | **Bazenheid** | ELEX | Bazenheid | CHE | Municipal Waste, Tail End | 51 m³ | 2008 |
| 150. | **Eunpyung MSWI** | Eco En Top | | KOR | Municipal Waste | 5 m³ | 2008 |
| 151. | **Myungji MSWI** | SPECO | SPECO | KOR | Municipal Waste Additional Delivery | 25 m³ | 2008 |
| 152. | **Haewundae MSWI** | Busan Environmental Corp | Busan Environmental Corp | KOR | Municipal Waste, Additional Delivery | 17 m³ | 2008 |
| 153. | **MVA Zistersdorf** | BASF | Von Roll | AUT | Municipal Waste Tail End | 41 m³ | 2008 |
| 154. | **Mida Crotone** | Hafner | Mida S.r.l. | ITA | Municipal Waste, Tail End | 7 m³ | 2008 |
| 155. | **TBA Arnoldstein** | KRV | KRV | AUT | Municipal Waste Low Temperature, Additional Delivery | 6 m³ | 2008 |
| 156. | **Yangju MSWI Plant** | SPECO | SPECO | KOR | Municipal Waste | 13 m³ | 2008 |
| 157. | **Pangyo MSWI Plant** | SPECO | SPECO | KOR | Municipal Waste | 7 m³ | 2008 |
| 158. | **Masan MSWI Plant** | SPECO | SPECO | KOR | Municipal Waste | 5 m³ | 2008 |
| 159. | **Ferrara** | Alstom | HERA | ITA | Municipal Waste, Tail End, Low Temp. Additional Delivery | 44 m³ | 2008 |
| 160. | **Rimini** | Alstom | HERA | ITA | Municipal Waste, Tail End, Low Temperature | 44 m³ | 2008 |
| 161. | **Genf** | BASF | Usine de Cheneviers | CHE | Municipal Waste, Low Dust, Additional Delivery | 72 m³ | 2008 |
| 162. | **MVA Dürnrohr Linie 3** | Envirgy | AVN | AUT | Municipal Waste, Tail End | 35 m³ | 2009 |

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| 163. | **Mallorca P 3095** | BASF | TIRME SA | ESP | Municipal Waste, Tail End | 45 m³ | 2009 |
| 164. | **Gwangmyeong** | Blue Bird | Blue Bird | KOR | Waste Heat Boiler | 9 m³ | 2009 |
| 165. | **MSW Giubiasco** | BASF | Von Roll | DEU | Municipal Waste, Tail End | 30 m³ | 2009 |
| 166. | **Kuri MSWI** | SPECO | SPECO | KOR | Municipal Waste, Low Dust | 18 m³ | 2009 |
| 167. | **Daejeon MSWI** | SPECO | SPECO | KOR | Municipal Waste | 6 m³ | 2009 |
| 168. | **Dadae MSWI** | MSWI Dadae | MSWI Dadae | KOR | Municipal Waste, Additional Delivery | 9 m³ | 2009 |
| 169. | **TBA Arnoldstein** | KRV | KRV | AUT | Municipal Waste Low Temperature, Additional Delivery | 8 m³ | 2009 |
| 170. | **NANYA** | BASF | Lucky Lotus Corp. | TWN | Industrial Waste Additional Delivery | 3 m³ | 2009 |
| 171. | **MVA Dordrecht** | BASF | LAB | NLD | Municipal Waste | 65 m³ | 2009 |
| 172. | **MVA Göteborg** | BASF | LAB | SWE | Municipal Waste | 39 m³ | 2009 |
| 173. | **Constanti** | BASF | | ESP | Residue, Low Dust, Additional Delivery | 3 m³ | 2009 |
| 174. | **MSW Reims** | Hamon | Hamon | FRA | Municipal Waste, Tail End Low Temperature | 31 m³ | 2009 |
| 175. | **Ulsan MSWI** | Halla Energy & Environment | | KOR | Municipal Waste, Additional Delivery | 10 m³ | 2009 |
| 176. | **Mapo MSWI** | Kolon | | KOR | Municipal Waste, Additional Delivery | 27 m³ | 2009 |
| 177. | **Chaumont** | HRC | SHMVD Chaumont | FRA | Municipal Waste, Tail End, Additional Delivery | 13 m³ | 2009 |
| 178. | **TABA Leudelange** | BASF | Von Roll / Sidor | LUX | Municipal Waste, Tail End Low Temperature | 47 m³ | 2010 |
| 179. | **Sivom Mulhouse** | Hamon | Sivom | FRA | Municipal Waste, Tail End | 61 m³ | 2010 |
| 180. | **MSW Sangju** | BASF | David Chemical | KOR | Municipal Waste | 3 m³ | 2010 |
| 181. | **MSWI Kimhae** | SPECO | | KOR | Municipal Waste, Additional Delivery | 10 m³ | 2010 |
| 182. | **MSWI Chungju** | SPECO | | KOR | Municipal Waste, Additional Delivery | 7 m³ | 2010 |
| 183. | **MSWI Yongin** | Kolon E&C | Yongin City | KOR | Municipal Waste, Additional Delivery | 7 m³ | 2010 |
| 184. | **MSWI Rennes** | BASF | Veolia | FRA | Municipal Waste, Tail End, Additional Delivery | 10 m³ | 2010 |
| 185. | **RHKW Linz** | Integral | Linz AG | AUT | Municipal Waste, Tail End | 40 m³ | 2010 |
| 186. | **Rhodia** | BASF | Rhodia | FRA | Residue Waste, Additional Delivery | 26 m³ | 2010 |
| 187. | **Sungseo MSWI # 3** | Sungseo | | KOR | Municipal Waste | 21 m³ | 2010 |
| 188. | **MSW Le Mans** | BASF | Veolia | FRA | Municipal Waste | 26 m³ | 2010 |
| 189. | **Mistral Spilimbergo** | Hafner | Hafner/Mistral Spilimbergo | ITA | Hospital Waste | 7 m³ | 2010 |

| Curr.No. | Project | Client | End user / Engineering company | Plant location | Application | Shipped quantity | Delivery date |
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| 190. | **T.A. Lauta** | BASF | T.A.Lauta GmbH | DEU | Municipal Waste, Tail End, Low Temp., Additional Delivery | 16 m³ | 2010 |
| 191. | **MSW Harlingen** | BASF | | DEU | Municipal Waste, Tail End | 37 m³ | 2010 |
| 192. | **Mataro Line 1+2** | Fuel Tech | TEM UTE Constructora | ITA | Municipal Waste | 23 m³ | 2010 |
| 193. | **Rhodia** | BASF | Rhodia | FRA | Residue Incineration, Additional Delivery | 26 m³ | 2010 |
| 194. | **Cenon** | BASF | Veolia | FRA | Municipal Waste, Tail End, Additional Delivery | 20 m³ | 2010 |
| 195. | **San Vittore Linie 2+3** | ATS Air Treatment System | MSWI San Vittore | ITA | Municipal Waste, Tail End | 65 m³ | 2010/2011 |
| 196. | **Forli** | Hera | Hera | ITA | Municipal Waste, Tail End, Additional Delivery | 21 m³ | 2011 |
| 197. | **HDO Incineration Freeport** | BASF | BASF | USA | Residue, Additional Delivery | 36 m³ | 2011 |
| 198. | **San Vittore Linie 1** | ATS Air Treatment System | MSWI San Vittore | ITA | Municipal Waste, Tail End | 23 m³ | 2011 |
| 199. | **MVA Moskau MSZ3** | Condor | EVN | RUS | Municipal Waste, Tail End | 30 m³ | 2011 |
| 200. | **Iksan DHP** | Samyoung Plant Co., Ltd. | Samyoung Plant Co., Ltd. | KOR | Waste Incineration (RDF&Coal) | 15 m³ | 2011 |
| 201. | **Namyangju MSWI** | Ilshin Environmental Co. | Ilshin Environmental Co. | KOR | Waste Incineration | 7 m³ | 2011 |
| 202. | **LWI BASF YPC Nanjing** | BASF | BASF YPC | CHN | Residue Incineration | 13 m³ | 2011 |
| 203. | **Dunkerque - Spare Layer 2011** | BASF | Von Roll | FRA | Waste Incineration, Additional Delivery | 4 m³ | 2011 |
| 204. | **MSWI Ulsan (New Line)** | Tong Yang Magic Co., Ltd. | Tong Yang Magic Co., Ltd. | KOR | Waste Incineration | 10 m³ | 2011 |
| 205. | **MSW Flamoval** | BASF | LAB | NLD | Municipal Waste, Tail End | 20 m³ | 2011 |
| 206. | **MSWI Kimpo** | Donglim Eng. Co. | Donglim Eng. Co. | KOR | Municipal Waste | 8 m³ | 2011 |
| 207. | **MSWI Dadae** | Kolon | Kolon | KOR | Municipal Waste, Additional Delivery | 8 m³ | 2011 |
| 208. | **MSWI Myungji** | Kolon | Kolon | KOR | Municipal Waste, Additional Delivery | 25 m³ | 2011 |
| 209. | **MSWI Haewundae** | Kolon | Kolon | KOR | Municipal Waste, Additional Delivery | 17 m³ | 2011 |
| 210. | **Colombes Ligne 2 & Ligne 3** | INTEGRAL | SIAAP | FRA | Sewage Sludge Incineration | 10 m³ | 2011 |
| 211. | **MSWI Kyungju** | Tong Yang Magic Co., Ltd. | Tong Yang Magic Co., Ltd. | KOR | Municipal Waste | 9 m³ | 2011 |
| 212. | **MSWI Torino** | BASF | LAB | ITA | Waste Incineration, Tail End, Low Temp. | 181 m³ | 2011 |
| 213. | **RDF MSWI Busan** | KIC | KIC | KOR | Municipal Waste | 29 m³ | 2011 |
| 214. | **MSWI Icheon** | Dongbu | Dongbu | KOR | Municipal Waste, Additional Delivery | 16 m³ | 2012 |
| 215. | **RVA Castrop Rauxel** | BASF | Thermtec | DEU | Residue Incineration | 3 m³ | 2012 |
| 216. | **KVA Zürich Hinwil** | BASF | Hitachi Zosen Inova | CHE | Municipal Waste, Low Temp. | 111 m³ | 2012 |

| Curr.No. | Project | Client | End user / Engineering company | Plant location | Application | Shipped quantity | Delivery date |
|---|---|---|---|---|---|---|---|
| 217. | **T.A. Lauta** | BASF | T.A.Lauta GmbH | DEU | Municipal Waste, Tail End, Low Temp. | 15 m³ | 2012 |
| 218. | **JGC C&C China project** | JGC C&C | Tongfang | CHN | Municipal Waste | 105 m³ | 2012 |
| 219. | **RSMVA Basel** | BASF | RSMVA Basel | CHE | Residue, Additional Delivery | 12 m³ | 2012 |
| 220. | **BASF Bologna** | BASF | BASF | ITA | Residue Incineration | 5 m³ | 2012 |
| 221. | **CVE d'Halluin Unit 1-3** | BASF | Elex | FRA | Municipal Waste, Tail End | 26 m³ | 2012 |
| 222. | **Acerra** | A2A | | ITA | Municipal Waste | 26 m³ | 2012 |
| 223. | **Ivry Unit 1+2** | BASF | Novergie | FRA | Municipal Waste, Low Dust, Dioxin/Furan, Additional Delivery | 156 m³ | 2012 |
| 224. | **MSWI Dadae** | Kolon | Busan City | KOR | Municipal Waste, Additional Delivery | 8 m³ | 2012 |
| 225. | **MSWI Myungji** | Kolon | Busan City | KOR | Municipal Waste, Additional Delivery | 25 m³ | 2012 |
| 226. | **H&H Bozen** | BASF | H&H Umwelttechnik GmbH | ITA | Municipal Waste | 31 m³ | 2012 |
| 227. | **MVA Prag** | Zauner | Pražske služby | CZE | Municipal Waste, Low Dust, Additional Delivery | 7 m³ | 2012 |
| 228. | **Rhodia** | BASF | Rhodia | DEU | Residue Waste, Additional Delivery | 17 m³ | 2012 |
| 229. | **EEW Delfzijl** | E.ON Delfzijl NL | E.ON Delfzijl NL | NLD | Municipal Wast | 20 m³ | 2012 |
| 230. | **Verbrennung DE #1** | CTP | Tridelta Thermprozess | DEU | Hazardous Waste | 4 m³ | 2012 |
| 231. | **Giubiasco** | BASF | Hitachi Zosen Inova | ITA | Municipal Waste, Tail End, Additional Delivery | 15 m³ | 2012/2013 |
| 232. | **AMSA** | A2A | AMSA | ITA | Waste Incineration, Low Temp., Additional Delivery | 87 m³ | 2012/2013 |
| 233. | **Ivry Unit 3+4** | BASF | Novergie | FRA | Municipal Waste, Low Dust, Dioxin/Furan, Additional Delivery | 156 m³ | 2013 |
| 234. | **MSW Lyon Nord** | BASF | Sita | FRA | Municipal Waste, Tail End | 51 m³ | 2013 |
| 235. | **MVA Prag** | Zauner | Pražske služby | CZE | Municipal Waste, Low Dust, Additional Delivery | 15 m³ | 2013 |
| 236. | **Anyang MSWI** | Coreco Co. | Anyang MSWI | KOR | Municipal Waste | 10 m³ | 2013 |
| 237. | **MSW Ludres** | Hamon Environmental s.a.r.l. | Nancy Energie | FRA | Municipal Waste, Tail End, Low Temperature with Regeneration | 20 m³ | 2013 |
| 238. | **Acerra 2013** | A2A | A2A | ITA | Municipal Waste Incineration with Dioxin | 26 m³ | 2013 |
| 239. | **Lasse** | BASF | Veolia | FRA | Municipal Waste, Tail End | 10 m³ | 2013 |
| 240. | **MVA Spittelau** | STRABAG AG | Wien Energie | AUT | Municipal Waste, Tail End, Low Temperature | 81 m³ | 2013 |
| 241. | **Pluzunet** | BASF | CNIM/LAB | FRA | Municipal Waste Incineration, Additional Delivery | 7 m³ | 2013 |
| 242. | **Sangju MSWI** | Sangju | Sangju | KOR | Waste Incineration, Additional Delivery | 3 m³ | 2013 |
| 243. | **Orlen Unit K6** | Babcock Noell | PKN | POL | Residue Oil Boiler | 61 m³ | 2013 |

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|---|---|---|---|---|---|---|---|
| 244. | **MSWI Colleferro** | Thermokimik | | ITA | Municipal Waste Incineration | 29 m³ | 2013 |
| 245. | **ACN Plant** | BASF | | CHN | Residue Incineration | 15 m³ | 2013 |
| 246. | **MSWI Bordeaux Spare Layer 2013** | BASF | | FRA | Waste Incineration, dioxine, Tail End | 14 m³ | 2013 |
| 247. | **MSWI Bordeaux Spare Layer 2014** | BASF | | FRA | Waste Incineration, dioxine, Tail End | 29 m³ | 2013 |
| 248. | **MSWI Yongin #2 + #3 Repl.** | Kolon Env.Co./Yongin City | Kolon Env.Co./Yongin City | KOR | Waste Incineration | 13 m³ | 2013 |
| 249. | **Dioxin Kat Israel** | BASF | | DEU | Residue Incineration plant | 3 m³ | 2013 |
| 250. | **Acerra part 2 - 2013** | A2A | A2A | ITA | Municipal Waste Incineration with Dioxin | 26 m³ | 2014 |
| 251. | **MVA Prag Spare Layer** | Zauner | | CZE | Municipal Waste Incinerator, Low Dust | 30 m³ | 2014 |
| 252. | **MSWI Mapo** | Kolon | MSWI Kolon | KOR | Municipal Waste Incinerator, Additional Delivery | 27 m³ | 2014 |
| 253. | **Rhodia** | BASF | Rhodia | FRA | Residue Incinerator, Additional Delivery | 17 m³ | 2014 |
| 254. | **HDO Incineration Freeport** | BASF | BASF | USA | Residue Incineration | 36 m³ | 2014 |
| 255. | **West Palm Beach Unit 1, 2, 3** | Babcock & Wilcox | Solid Waste Authority of Palm Beach | USA | Municipal Waste, Tail End | 95 m³ | 2014 |
| 256. | **Creteil** | BASF | CIE | FRA | Municipal Waste, Tail End, Additional Delivery | 24 m³ | 2014 |
| 257. | **MSW Haidian** | BASF | | CHN | Municipal Waste, Tail End | 47 m³ | 2014 |
| 258. | **Schwarzheide** | BASF | BASF | DEU | Residue Incinerator, Additional Delivery | 10 m³ | 2014 |
| 259. | **CVDU Nice** | BASF | LAB | FRA | Municipal Waste, Tail End, Dioxin Additional Delivery | 24 m³ | 2014 |
| 260. | **Borsodchem** | BASF | Borsodchem ZRT | HUN | Municipal Waste, Tail End Additional Delivery | 8 m³ | 2014 |
| 261. | **MSW Chotikov** | Zauner Anlagenbau GmbH | Skládka Chotíkov | CZE | Municipal Waste, Tail End, Dioxin | 29 m³ | 2014 |
| 262. | **Mistral Spilimbergo** | Mistral FVG S.R.L. | Mistral FVG S.R.L. | ITA | Hospital Waste, Additional Delivery | 3 m³ | 2014 |
| 263. | **MSWI Gyeongsan** | EG Corp. | | KOR | Municipal Waste Incinerator | 5 m³ | 2014 |
| 264. | **MSWI New Cheongju** | EG Corp. | | KOR | Municipal Waste Incinerator | 4 m³ | 2014 |
| 265. | **Saint Ouen** | BASF | | FRA | Waste Incineratior, Tail End | 25 m³ | 2014 |
| 266. | **KVA Hagenholz** | BASF | KVA Hagenholz | CH | Municipal waste incineration, Low Dust | 50 m³ | 2014 |
| 267. | **Saint Ouen** | BASF | | FRA | Waste Incineratior, Tail End | 24 m³ | 2014 |
| 268. | **MSWI Modena** | ATS | MSWI Modena | ITA | Waste Incineration Tail End | 17 m³ | 2014 |
| 269. | **BASF N800** | BASF | BASF | DEU | Residue Waste Incineration Low Dust; Additional Delivery | 117 m³ | 2014 |
| 270. | **MSWI Eunpyung** | UET Engineering Co. | Eunpyung MSWI | KOR | Waste Incineration; Additional Delivery | 5 m³ | 2014 |

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| 271. | **Sarpi Dorog** | BASF | | HUN | Residue Incinerator | 8 m³ | 2014 |
| 272. | **BASF C 19.8700** | BASF | BASF | CHN | Residue Waste Incineration | 4 m³ | 2015 |
| 273. | **BASF C 19.8730** | BASF | BASF | CHN | Residue Waste Incineration | 5 m³ | 2015 |
| 274. | **MSWI Icheon** | Dongbu Construction | Icheon City | KOR | Municipal Waste; Additional Delivery | 16 m³ | 2015 |
| 275. | **JGC China / BN Project** | JGC Catalysts & Chemicals Ltd. | Tongfang | CHN | Waste Incineration Tail End | 59 m³ | 2015 |
| 276. | **Orlen K4** | Babcock Noell GmbH | PKN | PL | Residue Oil Boiler | 61 m³ | 2015 |
| 277. | **KVA Hagenholz Linie 2** | BASF | KVA Hagenholz | CH | Waste Incineration, Low Dust | 51 m³ | 2015 |
| 278. | **Dijon** | BASF | | FRA | Waste Incinerator; Tail End | 26 m³ | 2015 |
| 279. | **Saint Ouen** | BASF | | FRA | Waste Incineration Tail End; Additional Delivery | 24 m³ | 2015 |
| 280. | **Colleferro** | Termokimik Corp. | C.T.E. Colleferro | ITA | Municipal Waste Incinerator; Additional Delivery | 10 m³ | 2015 |
| 281. | **Schwarzheide** | BASF | BASF | DEU | Residue Incineration, Additional Delivery | 10 m³ | 2015 |
| 282. | **Creteil** | BASF | CIE | FRA | Municipal Waste, Tail End, Additional Delivery | 24 m³ | 2015 |
| 283. | **Nice Ligne 3-4** | BASF | LAB | FRA | Municipal waste incineration, Tail End | 30 m³ | 2015 |
| 284. | **Sukmoon DHP** | KOLON Env. Service Co. | | KOR | Waste Wood & RDF | 21 m³ | 2015 |
| 285. | **Amsa 3rd Layer** | A2A | A2A | IT | Municipal waste incineration, low temp. | 28 m³ | 2015 |
| 286. | **Beijing Chaoyang MSWI** | Beijing Golden State | | CHN | Municipal waste incineration | 66 m³ | 2015 |
| 287. | **MSWI Myungji** | Busan City | | CHN | Municipal waste incineration, Additional Delivery | 26 m³ | 2015 |
| 288. | **Filago** | Ecolombardia 4 / Boldrocchi Ecologia | | IT | Municipal waste incinerator, low temperature | 74 m³ | 2015 |
| 289. | **Daegu RDF** | Donglim Engineering | | KOR | Waste incineration | 17 m³ | 2015 |
| 290. | **Ulsan SRF** | Donglim Engineering | | KOR | Waste Incineration | 13 m³ | 2015 |
| 291. | **Mulhouse** | BASF | | FRA | Waste Incineration Tail End; Additional Delivery | 61 m³ | 2015 |
| 292. | **Rhodia Spare Layer** | BASF | Rhodia | FRA | Residue incineration; Additional Delivery | 32 m³ | 2015 |
| 293. | **Taizhou Delixi Waste Incinerator** | Changzhou Elex Environmental | | CHN | Hazardous Waste Incineration | 11 m³ | 2015 |
| 294. | **Saint Ouen Repl.** | BASF | | FRA | Waste Incineration Tail End; Additional Delivery | 97 m³ | 2016 |
| 295. | **Benesse Maremne** | BASF | | FRA | Municipal waste incineration | 12 m³ | 2016 |
| 296. | **Chengdu Wanxing MSWI** | Shanghai ZOSUM Engineering Co., Ltd. | | CHN | Municipal waste incineration | 86 m³ | 2016 |
| 297. | **BASF Pasadena** | BASF | | USA | Residue incineration plant | 9 m³ | 2016 |

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| 298. | **Orlen K2** | Babcock Noell | PKN | PL | Residue Oil Boiler | 49 m³ | 2016 |
| 299. | **BASF Pasadena 2nd + 3rd Layer** | BASF | BASF | USA | Residue incineration plant, Additional Delivery | 18 m³ | 2016 |
| 300. | **Rhodia Spare Layer** | BASF | | FRA | Residue incineration, Spare layer | 21 m³ | 2016 |
| 301. | **Mucha RIP** | Yara Taiwan | | TWN | Waste Incineration, Dioxin removal | 29 m³ | 2016 |
| 302. | **MSWI Rouen Unit 1-3** | BASF | | FRA | Waste incineration Tail end | 38 m³ | 2016 |
| 303. | **San Vittore L1 Additional Layer** | | Termomeccanica Ecologia | ITA | Waste Incineration Tail End; Additional D | 4.86 | 2016 |
| 304. | **Jeonju Power SRF** | EG Corp. | Samchullyes Co. | KOR | Municipal waste incineration | 26 m³ | 2016 |
| 305. | **MSWI Bordeaux** | BASF | Astria | FRA | Waste Incineration, Dioxine, Tail End, low temp.; Additional Delivery | 43 m³ | 2016 |
| 306. | **MSWI Tornino Spare Layer** | | IREN Energia | IT | Waste Incineration; Additional Delivery | 89 m³ | 2016 |
| 307. | **Aplex Cremator** | Aplex Cremator | Aplex | KOR | Cremator | 5 m³ | 2016 |
| 308. | **Nox Vent Treatment DOW** | DOW Olefinverbund GmbH | DOW Olefinverbund GmbH | | Residue incineration plant; Additional Delivery | 4 m³ | 2016 |
| 309. | **HDO Incineration Freeport** | BASF | BASF | USA | Residue incineration; Additional Delivery | 36 m³ | 2016 |
| 310. | **Constanti** | Envirotherm GmbH | SARPI | DEU | Residue incineration; Additional Delivery | 3 m³ | 2016 |
| 311. | **Colombes Ligne 2** | Le Gaz Integral | Le SIAAP | FRA | Waste Incineration; Additional Delivery | 5 m³ | 2016 |
| 312. | **CTO Project** | Tialoc (Shanghai) Environmental, Ltd | - | CHN | Waste gas furnance | 8 m³ | 2016 |
| 313. | **KVA Thurgau** | BASF | Elex | CH | Waste Incineration Tail End | 42 m³ | 2016 |
| 314. | **Asuwei MSWI** | Shanghai Dingtu Env. | | CHN | Waste Incineration | 119 m³ | 2016 |
| 315. | **Wenzhou Yongqiang MSWI** | Shanghai Dingtu Env. | Weiming | CHN | Waste Incineration | 74 m³ | 2016 |
| 316. | **Dabrowa Gornicza** | Envirotherm | SARPI | PL | Waste tail end | 8 m³ | 2016 |
| 317. | **Lyon Süd** | BASF | | FRA | Waste Incineration, Tail End, Low Temp. | 10 m³ | 2016 |
| 318. | **MSW Le Mans** | BASF | Veolia | FRA | Waste incineration tail end low temp.; Additional Delivery | 5 m³ | 2016 |
| 319. | **Saint Ouen Repl.** | BASF | | FRA | Waste Incineration Tail End; Additional Delivery | 49 m³ | 2017 |
| 320. | **Aplex Cremator (low dust)** | Aplex Cremator | Aplex | KOR | Crematory | 5 m³ | 2017 |
| 321. | **BASF C520** | BASF | | DEU | Residue waste incineration | 3 m³ | 2017 |
| 322. | **Pohang RDF** | Aerix Co. | Pohang City | KOR | Municipal Solid Waste Incinerator | 11 m³ | 2017 |
| 323. | **Soprano Ron** | Hamon Environmental s.a.r.l. | Sita Rekem | FRA | Municipal Waste; Additional Delivery | 15 m³ | 2017 |
| 324. | **Kwangju SRF** | KC Cottrell | Korea District Heating Coorp. | KOR | Municipal Solid Waste Iincinerator, Additional Delivery | 25 m³ | 2017 |

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| 325. | **MSWI Saint Thibault des Vignes Ligne 1+2** | | Suez Environment | IT | Waste incineration | 77 m³ | 2017 |
| 326. | **MSWI Shunyi** | Changzhou Elex Env. | Changzhou Elex Env. | CHN | Waste Incineration | 25 m³ | 2017 |
| 327. | **AMSA 3rd Layer part 2&3** | | A2A S.p.A. | IT | Muncipal waste incineration | 56 m³ | 2017 |
| 328. | **Issy-les-Monlineaux** | BASF | | FRA | Waste Incineration Tail End; Additional Delivery | 20 m³ | 2017 |
| 329. | **MSWI Torino Spare Layer** | | IREN S.p.A. | IT | Waste incineration | 29 m³ | 2017 |
| 330. | **MSWI Prague** | Zauner | Prazske Sluzby | CZE | Waste incineration low dust; Additional Delivery | 237 m³ | 2017 |
| 331. | **Constanti** | Envirotherm | SARPI | DEU | Residue Incineration; Additional Delivery | 19 m³ | 2017 |
| 332. | **Beijing Huairou MSWI** | Shanghai ZOSUM Engineering Co., Ltd. | Shanghai ZOSUM Engineering Co.Ltd. | CHN | Waste Incineration | 15 m³ | 2017 |
| 333. | **Dabrowa Gornicza** | Envirotherm | | PL | Waste Incineration Tail End; Additional Delivery | 8 m³ | 2017 |
| 334. | **Colombes Ligne** | Le Gaz Integral | SIAPP | FRA | Waste Incineration Tail End; Additional Delivery | 5 m³ | 2017 |
| 335. | **Yantai Wanhua TDI Incinerator** | Shanghai Dingtu | | CHN | Liquid hazardous waste incineration | 27 m³ | 2017 |
| 336. | **Cixi Zhongmao MSWI** | Shanghai Dingtu | | CHN | Municipal Solid Waste Incinerator | 55 m³ | 2017 |
| 337. | **Aplex Cremator High Dust** | Aplex Cremator | Aplex | KOR | Crematory | 10 m³ | 2017 |
| 338. | **Baoan 1st + 2nd Phase MSWI** | Shanghai Dingtu | | CHN | Municipal Solid Waste Incinerator | 130 m³ | 2017 |
| 339. | **Nanshan 1st Phase MSWI/** | Shanghai Dingtu | | CHN | Municipal Solid Waste Incinerator | 21 m³ | 2017 |
| 340. | **Aplex Cremator (Low dust)** | Aplex Cremator | Aplex | KOR | Crematory; Additional Delivery | 10 m³ | 2017 |
| 341. | **Bordeaux** | BASF | Astria | FRA | Waste Incineration, Tail End, Additional Delivery | 43 m³ | 2017 |
| 342. | **Oschatz Thermal Oxidizer** | Yara Environmental Protection (Qingdao) Co. Ltd | Oschatz | CHN | Waste liquids, Tail End | 10 m³ | 2017 |
| 343. | **Currenta SCR-1** | Envirotherm | Currenta | DEU | Residue Waste Incineration, Tail End | 22 m³ | 2017 |
| 344. | **KVA Zürich Hinwil** | BASF | KEZO Zweckverband Kehrichtverwertung Zürcher Oberland | CH | Waste, low temp. Additional Delivery | 28 m³ | 2017 |
| 345. | **Haeraeus Bitterfeld** | BASF | Steuler | DEU | Silicone-Oil incineration | 6 m³ | 2018 |
| 346. | **Cangnan MSWI** | Shanghai Dingtu Environmental | | CHN | Municipal Solid Waste Incinerator | 52 m³ | 2018 |
| 347. | **Qingzhou MSWI** | Shanghai Dingtu Environmental | | CHN | Municipal Solid Waste Incinerator | 36 m³ | 2018 |
| 348. | **Linyi MSWI** | Shanghai Dingtu Environmental | | CHN | Municipal Solid Waste Incinerator | 44 m³ | 2018 |
| 349. | **Taian MSWI** | Shanghai Dingtu Environmental | | CHN | Municipal Solid Waste Incinerator | 45 m³ | 2018 |
| 350. | **Rhodia** | BASF | Rhodia | FRA | Hazardous/Liquide Waste | 13 m³ | 2018 |
| 351. | **Currenta SCR II Leverkusen** | Andritz | Currenta | DEU | Residue Waste Incineration, Tail End | 39 m³ | 2018 |

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|---|---|---|---|---|---|---|---|
| 352. | **MSWI Lujiashan Repl.** | Shanghai Dingtu Environmental Engineering | | CHN | Municipal Waste Incinerator | 26 m³ | 2018 |
| 353. | **Orlen K4/K5/K6/K7** | PKN Orlen | PKN Orlen | POL | Residue Oil Boiler | 61 m³ | 2018 |
| 354. | **NOx Vent Treatment DOW** | DOW Olefinverbund GmbH | DOW Olefinverbund GmbH | DEU | Residue incineration plant, Additional Delivery | 4 m³ | 2018 |
| 355. | **Jiangbei MSWI** | Shanghai Dingtu | | CHN | Waste Incineration Tail End, Additional Delivery | 44 m³ | 2018 |
| 356. | **RuiAn MSWI** | Shanghai Dingtu | Weiming | CHN | Waste Incineration Tail End | 57 m³ | 2018 |
| 357. | **Coueron-Nantes** | BASF | Veolia | FRA | Waste Incineration Tail End, Additional Delivery | 6 m³ | 2018 |
| 358. | **Shougang Lujiashan MSWI (3 Lines)** | Shanghai Dingtu | Beijing Shougang | CHN | Waste Incineration Tail End | 79 m³ | 2018 |
| 359. | **Rhodia - Spare Layer 2+3/2018** | BASF | Rhodia | FRA | Liquide Waste Incineration | 34 m³ | 2018 |
| 360. | **Aplex Cremator (high dust)** | Aplex Cremator | Aplex | KOR | Crematory, Additional Delivery | 10 m³ | 2018 |
| 361. | **Aplex Cremator (low dust)** | Aplex Cremator | Aplex | KOR | Crematory, Additional Delivery | 10 m³ | 2018 |
| 362. | **Currenta SCR** | Currenta | | DEU | Toxic Waste, Low Dust | 22 m³ | 2018 |
| 363. | **MSWI Jeju** | S Tech Korea | | KOR | Waste Incineration, Tail End | 20 m³ | 2018 |
| 364. | **Qingdao MSWI** | Shanghai Dingtu Environmental | Kangheng | CHN | Municipal Solid Waste Incinerator | 71 m³ | 2018 |
| 365. | **Cixi Zhongmao MSWI 2nd phase** | Shanghai Dingtu Environmental | Huaxing East | CHN | Municipal Solid Waste Incinerator | 27 m³ | 2018 |
| 366. | **Colombes Ligne 2** | Le Gaz Integral | | FRA | Waste Incineration Tail End; Additional Delivery | 5 m³ | 2018 |
| 367. | **Wenling MSWI** | Shanghai Dingtu Environmental | Shanghai Zosum | CHN | Municipal Solid Waste Incinerator | 56 m³ | 2018 |
| 368. | **Hongbaoli** | Shanghai Dingtu Environmental | Shanghai Hoto | CHN | Municipal Solid Waste Incinerator | 8 m³ | 2019 |
| 369. | **Soprano PCX** | Hamon | Suez Environment | FRA | Chemical Waste Incinerator | 23 m³ | 2019 |
| 370. | **MSWI San Sebastian Unit 1+2** | | | ESP | Waste Incineration Tail End | 38 m³ | 2019 |
| 371. | **Puyang MSWI** | Shanghai Dingtu | Huaxing East | CHN | Waste Incineration, Tail End | 32 m³ | 2019 |
| 372. | **Gaoantun Medical Waste** | Shanghai Dingtu | Huaxing East | CHN | Medical Waste Incineration | 13 m³ | 2019 |
| 373. | **Zhuji Bafang MSWI** | Shanghai Dingtu Environmental | Zhejiang | CHN | Municipal Solid Waste Incinerator | 16 m³ | 2019 |