**BEFORE THE ILLINOIS POLLUTION CONTROL BOARD**

| | | |
|---|---|---|
| **IN THE MATTER OF:** | ) | |
| | ) | |
| **NITROGEN OXIDES EMISSIONS FROM** | ) | **R08-19** |
| **VARIOUS SOURCE CATEGORIES:** | ) | **(Rulemaking – Air)** |
| **AMENDMENTS TO 35 ILL.ADM.CODE** | ) | |
| **PARTS 211 AND 217.** | ) | |

**NOTICE OF FILING**

To:

John T. Therriault, Assistant Clerk
Illinois Pollution Control Board
James R. Thompson Center
Suite 11-500
100 West Randolph
Chicago, Illinois 60601

Persons included on the
**ATTACHED SERVICE LIST**

PLEASE TAKE NOTICE that we have today filed with the Office of the Clerk of the Pollution Control Board **TESTIMONY OF SCOTT MILLER AND KENT WANNINGER ON BEHALF OF MIDWEST GENERATION**.

Kathleen C. Bassi

Dated: November 25, 2008

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**CERTIFICATE OF SERVICE**

I, the undersigned, certify that on this 25th day of November, 2008, I have served electronically the attached **TESTIMONY OF SCOTT MILLER AND KENT WANNINGER ON BEHALF OF MIDWEST GENERATION** upon the following persons:

John T. Therriault, Assistant Clerk
Illinois Pollution Control Board
James R. Thompson Center
Suite 11-500
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Chicago, Illinois 60601

and electronically (except for Matthew J. Dunn) and by first class mail, postage affixed upon persons included on the **ATTACHED SERVICE LIST**.

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| **PARTS 211 AND 217.** | **)** | |

**TESTIMONY OF SCOTT MILLER**
**ON BEHALF OF MIDWEST GENERATION**

My name is Scott Miller. My testimony addresses the applicability provisions of the proposed rule to require the implementation of reasonably available control measures to reduce emissions nitrogen oxides through the imposition of reasonably available control technology or emission limitations designed to require the installation and operation of such equipment. This is commonly referred to as NOx RACT.

I am employed by Midwest Generation EME, LLC as an Environmental Program Manager – Air and am responsible for managing the air quality programs for the company's six coal-fired power stations in the State of Illinois. Specifically, I am responsible for overseeing compliance of the power stations with all applicable air quality programs, including the Acid Rain, NOx SIP Call, CAIR or its successor, ERMS, NSPS, NSR, Title V, HAPs, RACT, BART, and NAAQS programs as well as the state mercury program and any other air programs and requirements applicable to the power stations under state law. I have held this position with the company since 1999 and served in the same capacity from 1982 through 1999 as an employee of Commonwealth Edison Company, the previous owner and operator of these power stations. I began my career with ComEd in 1978 as an employee at the Zion Nuclear Station.

I received a Bachelor of Science degree in mechanical engineering from the University of Illinois at Urbana-Champaign in 1977 and a Master of Science degree in engineering management from Northwestern University in 1982.

I have 30 years of experience in the environmental field, including my 25 years of supervising the compliance of the power stations with air quality programs. As such, I am knowledgeable about Midwest Generation's compliance with air quality programs and the efforts it undertakes in order to comply with requirements applicable to the power stations.

Midwest Generation, LLC owns, in whole or in part, and operates five electric generation stations in the Chicago nonattainment area. These are the Waukegan Generating Station, located in Waukegan in Lake County; the Fisk and Crawford Generation Stations, located in Chicago; the Will County Generation Station, located near Romeoville in Will County; and the Joliet Generating Station, located in Joliet, also in Will County. Midwest Generation also owns and operates the Powerton Generating Station, located in Tazewell County near Pekin; Powerton is not subject to these proposed rules. The five stations in the Chicago area are capable of generating 4,422 megawatts, approximately 26% of the total coal-fired generation currently operating in the state.

One of Midwest Generation's general concerns with the proposed rule is with the applicability language of Subpart M. As proposed, the applicability of Subpart M depends upon a unit's being subject to the Illinois Clean Air Interstate Rule ("CAIR") codified at Part 225, Subparts C, D, and E. My understanding is that the federal CAIR is still in place even though the court, in its opinion on the appeal of the federal CAIR, found that the federal CAIR was so seriously flawed that it has to be vacated. It is still in place because the court has not yet ordered that the vacatur be implemented. I also understand that the court is considering whether it should rehear arguments on certain portions of the appeal and whether it should stay its mandate or not order the vacatur to be implemented for some period of time so that the federal CAIR remains in place. However, as of the date of this testimony, the court had not completed its deliberations, and we do not know whether the federal CAIR will remain in place or will be vacated.

We interpret the proposed applicability language for Subpart M to say that Subpart M applies to EGUs if they are subject to the Illinois CAIR. However, it is not clear to us that the Illinois CAIR will remain a viable or valid rule if the federal CAIR is actually vacated. In its response to Midwest Generation's pre-filed question # 6, the agency stated that it does not agree with the underlying premise of the question, *i.e.*, that upon issuance of the D.C. Circuit Court of Appeals' mandate in the appeal of the federal CAIR, *North Carolina v. EPA,* which will vacate the federal rule, the state rule will be invalid. Midwest Generation intends to provide further briefing on this point in its comments.

Assuming, though, that our interpretation is correct or at least reasonable, if the federal CAIR is vacated and the Illinois CAIR is no longer a valid rule, then Subpart M does not apply to EGUs. If that is the case, then the exemption for EGUs included in CPS and MPS groups do not apply as well.

In testimony responding to Midwest Generation's pre-filed questions # 6 and # 20 posed to the Agency's witnesses, the Agency has proposed an amendment to the applicability language. That amended language accomplishes the Agency's intent and is acceptable to Midwest Generation. Midwest Generation encourages the Board to adopt this amendatory language rather than the originally proposed applicability language for Subpart M.

Midwest Generation believes that it could achieve an emission rate of 0.15 lb/mmBtu at each of its Chicago-area generating stations within the cost-effectiveness scope defined by the

Agency for this rulemaking, if the exemption applicable to CPS sources should, for some unforeseen reason, no longer apply. As Mr. Wanninger has testified, Midwest Generation does not believe that the 0.09 lb/mmBtu rate proposed by the Agency in Section 217.344(a) is RACT.

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**TESTIMONY OF KENT WANNINGER**
**ON BEHALF OF MIDWEST GENERATION**

My name is Kent Wanninger. My testimony addresses a number of the technical and economic issues raised by the proposed rule to require the implementation of reasonably available control measures to reduce emissions nitrogen oxides through the imposition of reasonably available control technology or emission limitations designed to require the installation and operation of such equipment, commonly referred to as NOx RACT.

I am employed by Midwest Generation EME, LLC as a Director, Environmental Controls & Strategy. I am responsible for providing technical expertise for the development of pollution control strategies for Midwest Generation. I have held this position for the past three years. I have had similar responsibilities for Midwest Generation since 1999.

I have been involved in power plant operations in the electric power industry since 1975. From 1975 through 1984 I was employed in various power plant capacities, including technical support, day-to-day station environmental compliance responsibilities, and plant supervisory roles in plant engineering and technical support. Between 1984 and 1989, I was responsible for managing and supervising the operations of a large fossil-fueled power station. In 1989, I moved to the corporate offices of Commonwealth Edison and through 1993 continued my career in the electric power industry as a project manager overseeing major capital projects for several coal and gas/oil-fired power plants. After 1993, I assume a corporate position to manage the Fossil Business Planning Group responsible for performing corporate strategic studies, including project feasibility studies and development of environmental compliance strategies for the Commonwealth Edison Fossil Generation Business Group. Other duties included the performance of engineering and economic studies on potential projects.

Over the course of my career, I have co-authored numerous technical papers and chaired various industry forums and conferences in the electric power industry.

I received my Bachelor of Science degree in Mechanical Engineering from Purdue University, West Lafayette, Indiana, in 1974.

Although, as Mr. Miller discusses in his testimony, we believe that with the amendments to the proposed applicability language of Subpart M Midwest Generation will be exempt from this NOx RACT rule, Midwest Generation believes there are a number of inaccuracies and incorrect assumptions and implications included in the Illinois Environmental Protection Agency's proposal and testimony that must be addressed. Midwest Generation appreciates that the Agency's assumption is that the solid fuel-fired electric generating units subject to this proposed rule will be exempt because they have all opted in to the Combined Pollutant Standard or Multi-Pollutant Standard. Nevertheless, the Agency found it necessary to include the emission rate; therefore, the rate deserves examination.

Coverage by the CPS does not erase the inaccuracies or incorrect analyses integral to this rule, and if for some unforeseen reason the CPS would no longer be applicable to Midwest Generation, it is possible that the limitations imposed by this rule could become applicable. Midwest Generation does not believe that an emission rate of 0.09 lb/mmBtu for solid fuel-fired boilers is RACT, particularly where the unit's baseline emission rate is considerably lower than the 0.4 or 0.5 that the Agency assumed in its analysis, as described in Dr. Staudt's response to Midwest Generation's pre-filed question # 21. There are clear limitations to SNCR technology when the baseline is as low as Midwest Generation's. Midwest Generation cannot comply with an emission rate of 0.09 lb/mmBtu of NOx at each of its generating stations located in the nonattainment area within the scope defined by the Agency as economically reasonable, $2500 to $3000 per ton.

The Agency did not perform an analysis of the EGUs in Illinois subject to this rulemaking. Rather, the Agency's Technical Support Document and testimony relied on information contained in the available literature, which is a reasonable basis for the Agency's analyses. Midwest Generation, however, is here providing an analysis of its ability to comply with this proposed rule. As the only EGUs in the Chicago nonattainment area subject to Subpart M, this analysis of the impact to Midwest Generation is the best information available, better than a mere literature review.

The EPA Fact Sheet, EPA-452/F-03-031, Attachment 1 hereto, reported that SNCR is able to achieve NOx removal efficiencies of 30% to 50%. However, in that same document, EPA stated that SNCR tends to be less effective at NOx levels lower than 200 to 400 ppm. All the tangentially-fired boilers operated by Midwest Generation at the Chicagoland power plants have previously been retrofitted with state-of-the-art low NOx burners and overfire air (TFS 2000 system) by the boiler original equipment manufacturer, Alstom, resulting in NOx emission rates in the range of 0.12 to 0.15 lb/mmBtu or in the range of around 60 to 70 ppm, significantly below the range cited in the EPA Fact Sheet.

Following the installation of these low NOx TFS 2000 systems, the boilers were tuned by Alstom field service engineers to obtain the maximum reduction in NOx emissions while limiting CO emissions to below permit limits. Any deeper staging of the low NOx firing systems to reduce the NOx emission rates would jeopardize compliance with the CO permit conditions.

Midwest Generation recently requested a proposal from Fuel Tech, a major supplier of SNCR NOx reduction technology, for the retrofit of an SNCR system at Will County Unit 4, a 529 megawatt twin furnace tangentially-fired boiler previously retrofitted with TFS 2000. Fuel Tech Proposal No. 08-B-027 is attached to this testimony (Attachment 2). The baseline NOx at Will County 4 is 0.13 lb/mmBtu. The Fuel Tech proposal provides for multiple levels of urea injection to maximize NOx removal while varying load and limiting ammonia slip to a maximum of 10 ppm, a key criteria used to specify the maximum performance potential of SNCR systems. Note that many SNCR systems limit ammonia slip to less than 5 ppm and sometimes less than 2 ppm, depending upon the sulfur content of the coal. Overdosing ammonia to increase NOx removal with an SNCR system resulting in excess ammonia slip is not a viable option. Ammonia slip must be limited based on several considerations:

- Excess amounts of ammonia in the flue gas can react with $SO_3$ produced in the combustion process to form ammonium bisulfate, which will form stick deposits as the flue gas cools across the air heater. This will progressively plug the air heater to the point where the unit must either reduce load or be forced off-line for cleaning. Note that ammonium bisulfate formation is more typically a problem with higher sulfur coal.
- Excess ammonia in the flue gas will also attach to the flyash, typically rendering it unusable for beneficial reuse as a concrete admixture ingredient, resulting in the landfilling of the flyash. Additionally, excess ammonia captured in the flyash can result in ammonia vapors being released from the flyash during handling and landfilling, posing a personnel hazard.

- Excess ammonia slip that exits the stack can result in additional condensable stack PM2.5 emissions.

Based on the low inlet NOx emission rate of Will County 4, Fuel Tech responded in their SNCR proposal with a target NOx removal rate of 15% from baseline. Based on the 0.13 lb/mmBtu baseline NOx rate, Fuel Tech proposed a target SNCR NOx rate of 0.11 lb/mmBtu for Will County 4. However, Fuel Tech did not offer a firm guarantee even at a target NOx rate of 15%. Fuel Tech indicated that higher NOx removal rates were not achievable with the low inlet NOx rates at Will County 4.

The boiler configuration and NOx rate of Will County 4 is typical of the tangentially-fired boilers owned by Midwest Generation. The proposal from Fuel Tech does not come close to achieving the 0.09 lb/mmBtu NOx RACT rate proposed in this rulemaking.

With SNCR not a viable control technology for NOx RACT on the Midwest Generation Units, Midwest Generation must then consider alternatives such as SCR. Our analysis shows that SNCR technology will not achieve the proposed NOx RACT limit of 0.09 lbs/mmBtu since reductions of between 25% and 40% are required from our low baseline emissions between 0.12 and 0.15 lbs/mmBtu (averaged over the last four years) for our tangentially-fired boilers.

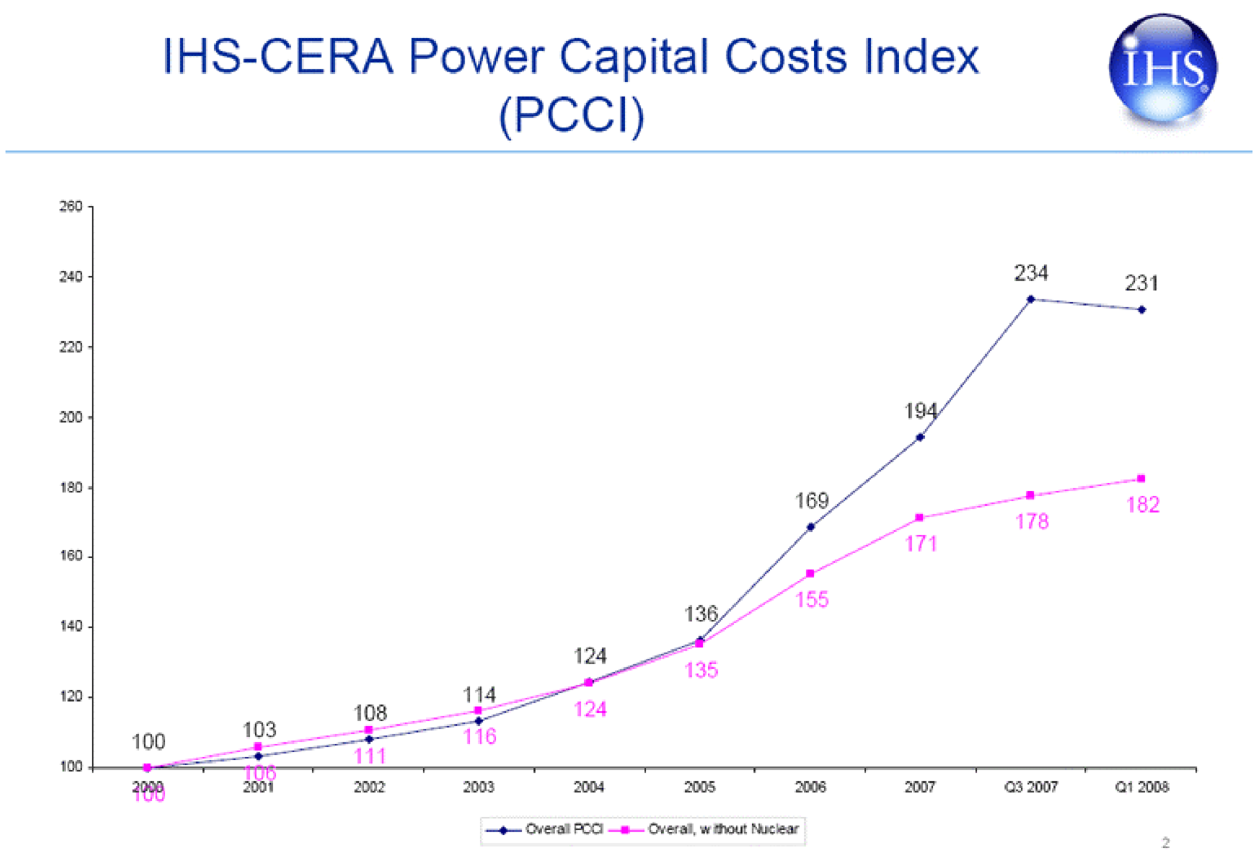
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| **Station/Unit** | **Boiler Type** | **MW Rating** | **Year 2004-2007 Annual Average NOx Rate (lbs/mmBtu)** | **NOx Rate with 15% Reduction (lbs/mmBtu)** | **Percent NOx Reduction to Achieve Rate of 0.09 lb/mmBtu (%)** | **Year 2007 Annual NOx Average (ppm)** | **Year 2007 Ozone Season NOx Average (ppm)** |
| **Crawford 7** | **T-fired** | **237** | **0.14** | **0.12** | **36%** | **63** | **57** |
| **Crawford 8** | **T-fired** | **347** | **0.15** | **0.13** | **40%** | **76** | **75** |
| **Fisk 19** | **T-fired** | **348** | **0.13** | **0.11** | **31%** | **65** | **66** |
| **Joliet 6** | **Cyclone** | **341** | **0.32**[1] | **0.27** | **72%** | **203** | **161** |
| **Joliet 7** | **T-fired** | **566** | **0.12** | **0.10** | **25%** | **52** | **53** |
| **Joliet 8** | **T-fired** | **561** | **0.12** | **0.10** | **25%** | **59** | **58** |
| **Waukegan 7** | **T-fired** | **359** | **0.14** | **0.12** | **36%** | **67** | **61** |
| **Waukegan 8** | **T-fired** | **385** | **0.13** | **0.11** | **31%** | **63** | **61** |
| **Will County 3** | **T-fired** | **281** | **0.14** | **0.12** | **36%** | **66** | **64** |
| **Will County 4** | **T-fired** | **551** | **0.14** | **0.12** | **36%** | **68** | **68** |

[1]Joliet 6 cyclone NOx rate averaged over the 2004-2007 ozone seasons only.

The Agency has stated that SNCR technology is expected to obtain a reduction of up to 30% reduction in NOx emissions. However, a 30% reduction from units with low baselines is insufficient for compliance. For example, the Fisk Generating Station has only one EGU. The average NOx rate at the Fisk EGU for 2004-2007 was 0.13 lb/mmBtu. A 30% reduction of a 0.13 lb/mmBtu rate achieves an emission rate of only 0.091 lb/mmBtu. With rounding, this would comply; without rounding, it would not. Midwest Generation is not willing to take that chance of noncompliance, which means that the reduction rate needs to ensure, very positively, that the unit would be in compliance. The rate at Fisk, then, would need to be lower than 0.09 lbs/mmBtu. Moreover, according to the proposal Midwest Generation received from Fuel Tech, we expect to achieve only a 15% reduction in NOx emissions from SNCR.

Because SNCR will not provide the necessary levels of reduction, in order to comply with this rule, Midwest Generation would have to install at least one SCR at each of its generating stations in the nonattainment area. Midwest Generation's experience is that it takes four years to install an SCR at operational conditions, from the point of the company making the decision to do so through initial operation, including obtaining financing. Therefore, if an SCR were required for compliance with this rule, Midwest Generation could not comply by the deadline of May 1, 2010.

Although the Agency has testified that SCR is or can be RACT, certainly for Midwest Generation it is not. The capital costs for retrofit SCRs today are much higher than reported even a few years ago. According to the IHI-CERA Power Capital Costs Index, a leading index that tracks the cost of equipment, facilities, materials, and personnel, reported costs in the coal power sector have increased 78% since 2000 with much of that increase occurring since 2006. *See* the attached IHI-CERA Power Capital Costs Index.




[www.ihsindexes.com](http://www.ihsindexes.com)

Midwest Generation developed a budgetary capital cost estimate for an SCR at the Powerton Station in 2005 and updated again in 2006 at a cost of approximately $240/kW in un-escalated 2006 dollars. Based on the escalation seen in the power sector, the cost of an SCR retrofit is now projected to approximate the $400/kW range seen in Wisconsin's Edgewater retrofit cost.[1] Based on the expected cost of an SCR of $400/kW, retrofitting SCRs at the Midwest Generation units located within the nonattainment area would result in a cost-effectiveness ranging from $21,000 to $32,000/ton for retrofit for the tangentially-fired units and over $7,000/ton for Joliet 6, a cyclone-fired boiler.

Clearly, the cost for Midwest Generation to comply with this rule is beyond the cost range that the Agency has described as RACT. Therefore, Subpart M is not economically reasonable, even though there is technology available that would enable Midwest Generation to meet the 0.09 lb/mmBtu limitation.

The U.S. Environmental Protection Agency stated that it would accept the Clean Air Interstate Rule as RACT. The statewide emission caps established in the CAIR were based upon a rate of 0.15 lb/mmBtu in 2009 and 0.125 lb/mmBtu in 2015. In evaluating the 2004 to /2007 annual average NOx emission rates at each of its units in the nonattainment area, Midwest Generation believes that it could comply with a rate of 0.15 lb/mmBtu using SNCR for the

[1] Recently, Wisconsin Power & Light and Wisconsin Electric Power Company filed a joint application with the Public Service Commission of Wisconsin to spend approximately $153.9 million or about $405/kW on the retrofit of an SCR at the 380 MW Edgewater Generating Station Unit 5 in Sheboygan, Wisconsin. These companies' experience demonstrates the effect of the rapid run-up in capital costs for SCRs today, compared to relying on data that is three to five years old. This is the most recent announcement of an SCR that we could find. Most SCRs built in the last few years were built for 2009 compliance with annual CAIR, and as such, most of the cost estimates were probably locked in three to five years ago and do not reflect current costs.

tangentially-fired units and SNCR plus Rich Reagent Injection for Joliet 6 within the cost range identified by the Agency.

This 0.15 lb/mmBtu rate, as RACT, would be more stringent than what USEPA stated it would accept in the CAIR because the CAIR assumed emissions trading. While the overall impact on the regional environment of an emissions trading program is the same or better than the impact of a command and control program, the command and control program is more stringent in the sense that a source does not have the opportunity to obtain allowances to cover any higher levels of emissions. For instance, under a trading program, Midwest Generation may choose not to control Waukegan where space is very limited but would control Joliet where there are larger units and more space. Under a RACT command and control program as proposed here, Waukegan would be required to comply with the 0.15 lb/mmBtu rate regardless of the additional costs imposed because of lack of space for more pollution control equipment.

To sum up Midwest Generation's position, an emission rate of 0.09 lb/mmBtu for solid-fueled EGUs is not RACT. Such a rate is not achievable at Midwest Generation's generating stations at a cost of $2500 to $3000 per ton. This is due, in part, to the fact that Midwest Generation's units already have a significantly lower NOx emission rate than the Agency assumed in its analyses. Lowering an already low rate is more costly than the Agency calculated. Moreover, the technology that the Agency assumed, *i.e.*, SNCR, does not exhibit the same efficiency in removing NOx when the baselines are so low. Midwest Generation would be forced to install SCR. SCR cannot be installed and operated at each generating station at a rate of $2,500 to $3,000 per ton. Rather, the cost is more approximately $7,000/ton to $32,000/ton per ton.

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EPA-452/F-03-031

# Air Pollution Control Technology Fact Sheet

**Name of Technology:** Selective Non -Catalytic Reduction (SNCR)

**Type of Technology:** Control Device - Chemical reduction of a pollutant via a reducing agent.

**Applicable Pollutants:** Nitrogen Oxides ($NO_X$)

**Achievable Emission Limits/Reductions:**

$NO_X$ reduction levels range from 30% to 50% (EPA, 2002). For SNCR applied in conjunction with combustion controls, such as low $NO_X$ burners, reductions of 65% to 75% can be achieved (ICAC 2000).

**Applicable Source Type:** Point

**Typical Industrial Applications:**

There are hundreds of commercially installed SNCR systems on a wide range of boiler configurations including: dry bottom wall fired and tangentially fired units, wet bottom units, stokers, and fluidized bed units. These units fire a variety of fuels such as coal, oil, gas, biomass, and waste. Other applications include thermal incinerators, municipal and hazardous solid waste combustion units, cement kilns, process heaters, and glass furnaces.

**Emission Stream Characteristics:**

a. **Combustion Unit Size:** In the United States, SNCR has been applied to boilers and other combustion units ranging in size from 50 to 6,000 MMBtu/hr (5 to 600MW/hr) (EPA, 2002). Until recently, it was difficult to get high levels of NOx reduction on units greater than 3,000 MMBtu (300 MW) due to limitations in mixing. Improvements in SNCR injection and control systems have resulted in high $NO_X$ reductions (> 60%) on utility boilers greater than 6,000 MMBtu/hr (600MW). (ICAC, 2000).

b. **Temperature:** The $NO_X$ reduction reaction occurs at temperatures between 1600°F to 2100°F (870°C to 1150°C) (EPA, 2002). Proprietary chemicals, referred to as enhancers or additives, can be added to the reagent to lower the temperature range at which the $NO_X$ reduction reactions occur.

c. **Pollutant Loading:** SNCR tends to be less effective at lower levels of uncontrolled $NO_X$. Typical uncontrolled $NO_X$ levels vary from 200 ppm to 400 ppm (NESCAUM, 2000). SNCR is better suited for applications with high levels of PM in the waste gas stream than SCR.

d. **Other Considerations:** Ammonia slip refers to emissions of unreacted ammonia that result from incomplete reaction of the $NO_X$ and the reagent. Ammonia slip may cause: 1) formation of ammonium sulfates, which can plug or corrode downstream components, 2) ammonia absorption into fly ash, which may affect disposal or reuse of the ash, and 3) increased plume visibility. In the U.S., permitted ammonia slip levels are typically 2 to 10 ppm (EPA, 2002). Ammonia slip at these levels do not result in plume formation or pose human health hazards. Process optimization after installation can lower slip levels.

Nitrous Oxide ($N_2O$) is a by-product formed during SNCR. Urea based reduction generates more $N_2O$ than ammonia-based systems. At most, 10% of the $NO_X$ reduced in urea-based SNCR is converted to $N_2O$. Nitrous oxide does not contribute to ground level ozone or acid formation. (ICAC,2000)

**Emission Stream Pretreatment Requirements:** None

**Cost Information:** All costs are in year 1999 dollars. (NESCAUM, 2000; ICAC, 2000; and EPA, 2002)

The difficulty of SNCR retrofit on existing large coal-fired boilers is considered to be minimal. However, the difficulty significantly increases for smaller boilers and packaged units. The primary concern is adequate wall space within the boiler for installation of injectors. Movement and/or removal of existing watertubes and asbestos from the boiler housing may be required. In addition, adequate space adjacent to the boiler must be available for distribution system equipment and for performing maintenance. This may require modifications to ductwork and other boiler equipment.

A typical breakdown of annual costs for industrial boilers will be 15% to 35% for capital recovery and 65% to-85% for operating expense (ICAC,2000). Since SNCR is an operating expense-driven technology, its cost varies directly with $NO_X$ reduction requirements and reagent usage. Optimization of the injection system after start up can reduce reagent usage and, subsequently, operating costs. Recent improvements in SNCR injection systems have also lowered operating costs.

There is a wide range of cost effectiveness for SNCR due to the different boiler configurations and site-specific conditions, even within a given industry. Cost effectiveness is impacted primarily by uncontrolled $NO_X$ level, required emissions reduction, unit size and thermal efficiency, economic life of the unit, and degree of retrofit difficulty. The cost effectiveness of SNCR is less sensitive to capacity factor than SCR. Control of $NO_X$ is often only required during the ozone season, typically June through August. Since SNCR costs are a function of operating costs, SNCR is an effective control option for seasonal $NO_X$ reductions.

Costs are presented below for industrial boilers greater than 100 MMBtu/hr.

a. **Capital Cost:** 900 to 2,500 $/MMBtu/hr (9,000 to 25,000 $/MW)

b. **O&M Cost:** 100 to 500 $/MMBtu/hr (1,000 to 5,000 $/MW)

c. **Annualized Cost:** 300 to 1000 $/MMBtu/hr (3,000 to 10,000 $/MW)

d. **Cost per Ton of Pollutant Removed:**

**Annual Control**: 400 to 2,500 $/ton of $NO_X$ removed
**Seasonal Control**: 2,000 to 3,000 $/ton of $NO_X$ removed

**Theory of Operation:**

SNCR is based on the chemical reduction of the $NO_X$ molecule into molecular nitrogen ($N_2$) and water vapor ($H_2O$). A nitrogen based reducing agent (reagent), such as ammonia or urea, is injected into the post combustion flue gas. The reduction reaction with $NO_X$ is favored over other chemical reaction processes at temperatures ranging between 1600°F and 2100°F (870°C to 1150°C), therefore, it is considered a selective chemical process (EPA, 2002).

Both ammonia and urea are used as reagents. Urea-based systems have advantages over ammonia based systems. Urea is non-toxic, less volatile liquid that can be stored and handled more safely. Urea solution droplets can penetrate farther into the flue gas when injected into the boiler, enhancing the mixing with the flue gas which is difficult in large boilers. However, urea is more expensive than ammonia. The Normalized Stoichiometric Ratio (NSR) defines the ratio of reagent to $NO_X$ required to achieve the targeted $NO_X$ reduction. In practice, more than the theoretical amount of reagent needs to be injected into the boiler flue gas to obtain a specific level of $NO_X$ reduction.

In the SNCR process, the combustion unit acts as the reactor chamber. The reagent is generally injected within the boiler superheater and reheater radiant and convective regions, where the combustion gas temperature is at the required temperature range. The injection system is designed to promote mixing of the reagent with the flue gas. The number and location of injection points is determined by the temperature profiles and flow patterns within the combustion unit.

Certain application are more suited for SNCR due to the combustion unit design. Units with furnace exit temperatures of 1550°F to 1950°F (840°C to 1065°C), residence times of greater than one second, and high levels of uncontrolled $NO_X$ are good candidates.

During low-load operation, the location of the optimum temperature region shifts upstream within the boiler. Additional injection points are required to accommodate operations at low loads. Enhancers can be added to the reagent to lower the temperature range at which the $NO_X$ reduction reaction occurs. The use of enhancers reduces the need for additional injection locations.

**Advantages:**

- Capital and operating costs are among the lowest of all $NO_X$ reduction methods.
- Retrofit of SNCR is relatively simple and requires little downtime for large and medium size units.
- Cost effective for seasonal or variable load applications.
- Waste gas streams with high levels of PM are acceptable.
- Can be applied with combustion controls to provide higher $NO_X$ reductions.

**Disadvantages:**

- The waste gas stream must be within a specified temperature range.
- Not applicable to sources with low $NO_X$ concentrations such as gas turbines.
- Lower $NO_X$ reductions than Selective Catalytic Reduction (SCR).
- May require downstream equipment cleaning.
- Results in ammonia in the waste gas stream which may impact plume visibility, and resale or disposal of ash.

**References:**

EPA, 1998. U.S. Environmental Protection Agency, Innovative Strategies and Economics Group, "Ozone Transport Rulemaking Non-Electricity Generating Unit Cost Analysis", Prepared by Pechan-Avanti Group, Research Triangle Park, NC. 1998.

EPA, 1999. US Environmental Protection Agency, Clean Air Technology Center. "Technical Bulletin: Nitrogen Oxides ($NO_X$ ), Why and How They Are Controlled". Research Triangle Park, NC. 1998.

EPA, 2002. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. *EPA Air Pollution Control Cost Manual*, Section 4 Chapter 1. EPA 452/B-02-001. 2002. http://www.epa.gov/ttn/catc/dir1/cs4-2ch1.pdf

ICAC, 2000. Institute of Clean Air Companies, Inc. "White Paper: Selective Non-Catalytic Reduction (SNCR) for Controlling $NO_X$ Emissions". Washington, D.C. 2000.

NESCAUM, 2000. Northeast States for Coordinated Air Use Management. "Status Reports on $NO_X$ Controls for Gas Turbines, Cement Kilns, Industrial Boilers, and Internal Combustion Engines: Technologies & Cost Effectiveness". Boston, MA. 2002.

FUEL TECH®

*Technologies to enable clean efficient energy™*

# PROPOSAL NO. 08-B-027

## $NO_x$OUT® SNCR

TO

## MIDWEST GENERATION

FOR

## WILL COUNTY STATION

## UNIT 4

## April 21, 2008

## EXECUTIVE SUMMARY

In support of efforts underway at Midwest Generation to provide low cost NOx reduction technologies for its coal generating facilities, Fuel Tech is pleased to provide equipment scope, pricing, and NOx reduction performance for the NOxOUT® selective non-catalytic reduction (SNCR) for Will County Generating Station Unit 4.

This unit is a CE T-fired twin furnace, with a capacity of 4850 MMBtu/hr and fires PRB coal. This proposal provides NOx reduction information at 100% load with a 15% NOx reduction at 10ppm ammonia slip. This information is outlined in more detail in our Process Design Table located in Section 4 of this Offering.

This Proposal describes in detail the engineering, design, and equipment proposed for the NOx reduction system. The equipment and service descriptions are detailed in Section 5 and have been based on our standard equipment standards and specifications (Section 10).

The Scope of Supply by Others is detailed in Section 6 of this Offering. The pricing for capital equipment and engineering scope of supply (Fuel Tech) is provided in Section 7. Installation engineering, installation labor and material, and installation project management shall be provided by others and is not included here. Included in Section 8 are Fuel Tech's standard terms and conditions while the preliminary project schedule is included in Section 9. The NOxOUT® A reagent information and MSDS, as well as the licensed suppliers list, are detailed in Section 11 of this Offering.

**FUEL TECH, INC.**

Fuel Tech is the world's leading supplier of urea-based SNCR, SCR, Cascade® (Hybrid SNCR/SCR), and RRI Systems with 450+ installations of which one hundred (100) NOxOUT® systems are installed on utility boilers. The SNCR technology is marketed under the trade name NOxOUT®. Fuel Tech's experience is detailed in the Experience List included in Section 12 of this proposal.

## TECHNOLOGY DESCRIPTION

### DESCRIPTION OF THE NOxOUT® SNCR PROCESS

The NOxOUT® Process is a post-combustion NOx reduction method that reduces NOx through a controlled injection of NOxOUT® A or other NOxOUT® reagents into the combustion gas path of fossil-fired and waste-fired boilers, furnaces, incinerators, or heaters. NOxOUT® A is a 50% urea solution plus a small amount of additives for scale and corrosion control. This reagent is readily available and requires no special safety precautions for handling.

The use of urea for control of oxides of nitrogen was developed under the sponsorship of the Electric Power Research Institute (EPRI) between 1976 and 1981. Fuel Tech is EPRI's exclusive licensing agent for the urea based technology. These early investigations provided fundamental thermodynamic and kinetic information of the NOx-urea reaction chemistry and identified some traces of by-products. The predominant overall reaction is described as:

$$CO(NH_2)_2 + 2NO + 1/2\ O_2 \Rightarrow 2N_2 + CO_2 + 2H_2O$$

Urea + Nitrogen Oxide ⇒ Nitrogen + Carbon Dioxide + Water

Though some trace quantities of ammonia and carbon monoxide may form, the quantities of these can often be controlled through application know-how.

The NOx removal efficiency and reagent utilization are related by a variable known as Normalized Stoichiometric Ratio (NSR). This ratio is defined as shown below. NOxOUT® A utilization is equal to the NOx reduction divided by NSR.

$$NSR = \frac{\text{Actual Molar Ratio of Reagent to Inlet NOx}}{\text{Stoichiometric Molar Ratio of Reagent to Inlet NOx}}$$

Fuel Tech has expanded the technology by developing chemical injection hardware, widening the applicable temperature range, and process control expertise required for commercial applications. Fuel Tech's licensing agreement with EPRI, combined with its successful in-house developments, is marketed commercially under the trade name NOxOUT®.

Two key parameters that affect the process performance are flue gas temperature and the reagent distribution. The NOx reducing reaction is temperature sensitive; by-product emissions become significant at lower than the optimum temperature range while chemical utilization and NOx reduction decrease at higher than the optimum. This optimum temperature range is specific to each application. The reagent needs to be distributed within this optimum temperature zone to obtain the best performance. Typically, the distribution is more difficult for large units and for units with high flue gas velocity.

The NOxOUT® Process is designed with the aid of Computational Fluid Dynamics (CFD) and Chemical Kinetic Model (CKM) in addition to results from field tests. The CFD model simulates flue gas flows and temperature inside a unit while the CKM calculates the reaction between urea and NOx based on temperature and flow information from CFD.

## TECHNOLOGY DESCRIPTION
(-Continued-)

A combination of these two models determines the optimum temperature region and the optimum injection strategy to distribute the reagent. With an ability to estimate NOx reduction, a model study can be performed to determine if an application is a right fit for the process.

Utilizing pressurized air, these injectors atomize and direct the NOxOUT® reagents into the combustion gas path. The droplet size distribution and spray coverage developed by the injectors promote efficient contact between the NOxOUT® reagents and the NOx in the flue gas.

The NOxOUT® Process provides effective boiler load following capabilities. Through the computer modeling, an injection strategy is developed that makes use of multilevel injection, control of reagent concentration, droplet size and spray patterns.

Several years of field testing indicate that the NOxOUT® Process is applicable on various types of units firing many different fuels. The process was successfully proven on units fired with coal, oil, gas, wood or municipal solid or hazardous waste. These units varied in size and type: package boilers, process heaters, incinerators, circulating or bubbling fluidized beds, waste heat boilers, utility boilers. By virtue of being a post-combustion process, unit size and type and fuel type have some, but not a major effect on the process.

There are substantial benefits gained from the application of the NOxOUT® Process compared to first generation NOx control technologies, such as ammonia injection. These benefits are briefly summarized below:

- Use of non-toxic, non-hazardous chemicals.
- Potentially lower capital cost due to the lack of large system compressors and elimination of anhydrous ammonia storage, handling, and safety equipment.
- Lower operating costs resulting primarily from minimization of gas (steam or compressed air) requirements.
- Inherently more effective control of spray patterns and chemical distribution for better mixing with the use of liquid rather than gas-based reagents, thereby resulting in better chemical utilization.

Midwest Generation
Will County Station #4
NOxOUT® SNCR System

Proposal 08-B-027
April 21, 2008


## PROCESS DESIGN TABLE

**Process Parameters Per Unit Basis - SNCR**

| | |
|---|---|
| Unit Identification | Will County Unit 4 |
| Type of Unit | CE T-Fired Twin Furnace |
| Type of Fuel | PRB |

| Case | | | Full Load |
|---|---|---|---|
| Load - 50-100% MCR | | MMBtu/hr | 4,850 |
| Baseline NOx | | lb/hr | 630.5 |
| Baseline NOx | | lb/MMBtu | 0.130 |
| SNCR Target NOx | | lb/MMBtu | 0.110 |
| SNCR Reduction | | % | 15 |
| Average NH3 Slip (uncorrected) | | ppmd | 10 |
| Provided Temperature - Upper Furnace | | °F | 2100 |
| Provided Furnace CO - Upper Furnace | | ppmd | 100 |
| NOxOUT - A | | gph | 96 |
| Injectors per Boiler | Level One | Sixteen (17) Automatic Retract Injectors | |
| | Level Two | Ten (10) Wall Injectors | |
| | Level Three | Six (6) Multiple Nozzle Lances (25' Insertion Length) | |

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY

**FUEL TECH EQUIPMENT SCOPE OF SUPPLY - SNCR**

| Equipment Description | Quantity |
|---|---|
| Reagent Storage Tank, FRP, Pre-Fabricated, Heat Traced and Insulated | One (1) 15,000 Gallon |
| High Flow Circulation Module w/Building w/PLC and Chemical Circulation Pressure Control | One (1) HFD w/Building Common to All Units |
| **Equipment Located in Building Near Boiler(s)** | |
| Dilution Water Module w/Remote I/O | One (1) - DWP Modules |
| Injection Zone Metering Modules w/PLC | Two (2) - IZM - 2 Zone |
| Distribution Modules (Indoor) | Four (4) - DM-4<br>Two (2) - DM-5 |
| **Equipment Located at Boiler** | |
| Wall Injectors | Twenty-Six (26) - SLP3-I-FTL |
| Automatic Retracts | Sixteen (16) - SLP3-AR |
| Automatic Retract Control Panels | Four (4) |
| Multiple Nozzle Lance Distribution Modules | Two (2) - MNL-DM3 |
| Multiple Nozzle Lances | Six (6) - MNL's, 25' Inserted Length |
| MNL Cooling Water and Air Control | One (1) |
| Temperature Monitors | One (1) |
| Man-days Start-up/Optimization/Training | One Hundred (100) |

**15,000 FRP NOxOUT®A STORAGE TANK**
Made of Fiberglass Reinforced Plastic (FRP) with Premium Grade Vinylester Resin. Fabricated per ASTM D3299 where applicable, 1.15 Specific Gravity heating package to maintain 80 °F, site specific variables include seismic zone and windload.

Also includes level transmitter, man-way, vent, internal downpipe, external fill pipe, ladder, hold down and lifting lugs, FRP flanges for inlet, outlet, and fill and circulation line valves for suction isolation, drain, and return control. Also included is heat trace and insulation with thermostat control. One Control Panel will be provided per tank for temperature control of the 50% urea solution.

**Reference FTI Drawing C-1**

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY

(-Continued-)

### HIGH FLOW DELIVERY (HFD) AND CIRCULATION MODULE W/BUILDING

The HFD Circulation Module is a self-contained high flow high head delivery system designed to supply filtered aqueous urea reagent to the Metering Module located near the reagent storage tank. An individual pump will be utilized to provide flow to each boiler, with a third pump as a common spare. This module serves multiple functions in the application of the Process on large industrial and utility scale boilers.

The functions include:

- Provides chemical boost for delivery of the reagent to the injection zones via the Injection Zone Metering Module.
- Filters 50% Urea Reagent to ensure trouble free operation of the injectors.
- Provides supplemental heating to makeup for line heating and losses and to maintain reagent above its crystallization temperature.
- Maintains a continuous circulation of the stored reagent.
- Serves as the local/remote control and monitoring station for the reagent storage and circulation system.
- Provides built-in redundancy to ensure continuous and uninterrupted operation.

This module contains two (2) full-flow multistage SS centrifugal pumps, in-line duplex strainer, in-line electric heater and all the pressure, temperature, flow and level instrumentation for local/remote control and monitoring of the HFD Circulation and urea storage systems.

The enclosures are constructed of fiberglass reinforced isopthalic plastic resin and molded-in color gel coat with ultraviolet inhibitors. Each building is specifically designed for the individual application with reinforced walls and flooring. Lifting lugs and structural design and analysis is performed where needed.

Each enclosure will include: Specified Fuel Tech, Inc. Equipment, Two (2) large service doors, heater, electrical outlets, lighting, electrical breaker panel with circuits and transformer specifically sized for application, and steel flooring system. All utility connections (except for electrical) will be made to exterior of the enclosures.
**Reference FTI Drawing J-10**

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY
(-Continued-)

### REAGENT PRESSURE CONTROL STATION

The pressure control loop regulates the 50% urea pressure for the High Flow Delivery Module supply to the Injection Zone Metering Modules in order to maintain the proper flowrate and pressure. The valve station maintains a sufficient chemical pressure upstream of the IZM's to allow for proper maintenance of 50% urea® flow. Each valve station is specifically sized for each application.

The system is a pre-fabricated piping spool piece consisting of a stainless steel pressure control valve, manual bypass valve, pressure transmitter, local pressure indicator, isolation valves, stainless steel piping, fittings, etc.
**Reference FTI Drawing J-7**

### DILUTION WATER PRESSURE (DWP) CONTROL MODULE

A self-contained high flow, high head pressure control and delivery system designed to supply filtered process dilution water to the Injection Zone Metering Module. The primary function of this module is to control the supply of dilution water on demand and act as the primary boost and control system for delivering the dilute NOxOUT® A reagent to the injection zones, via the Injection Zone Metering Module. Through the use of backpressure controllers and multistage pumps this system is designed to maintain a constant supply of dilution water at the design pressure, in response to changing process demands. In addition, this module filters the plant supplied dilution water through the use of an in-line duplex strainer thus ensuring trouble free operation of the injectors. The control panel will have local indication with AB remote I/O controlled by the IZM PLC.

This module contains two full-flow multistage SS centrifugal pumps, in-line duplex strainer, pressure control valves and all the pressure and flow instrumentation for local/remote control and monitoring of the NOxOUT®-U Dilution Water Pressure Control Module.
**Reference FTI Drawing M-2**

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY
(-Continued-)

### INJECTOR ZONE METERING (IZM) MODULE

The IZM is the primary module used to precisely meter and independently control the concentration of NOxOUT® A reagent to each zone of injection in a large Industrial or Utility Boiler application of the NOxOUT® process. This module, through the use of independent chemical flow control and zone pressure control valves integrated with local programmable PID controllers, provides an increased level of process control needed in these complex applications. This module is designed to interface with the plant Distributed Control System (DCS). The IZM Module automatically adjusts reagent flows and activates or deactivates injection zones or control zone mass flows, in response to changes in NOx level, boiler load, fuel or firing configurations. This unit will contain an AB SLC PLC with PanelView 1000 Operator Interface and an air conditioning unit to maintain appropriate internal panel operating temperatures.

Each zone sub-module of the IZM is designed to be operated and controlled independent of each other. This feature permits individual isolation of each sub-module for maintenance without severely impacting process performance or overall NOx reductions.

The standard unit includes a stainless steel, freestanding base with integrated containment basis, master interlock trip panel, instrument and atomizing air pressure switches and instrument air regulator. Each zone-metering sub-module includes local/remote selectors, manual/off/auto selection for flow and pressure control, local/remote process flow and pressure control with display, chemical and water control valves, and inline static mixer.
**Reference FTI Drawing M-3**

### SLP3-DM4 and DM5 DISTRIBUTION MODULES

These are placed just prior to the injectors (typically at the same elevation) and are used as a guide and check for proper injector performance. Air for atomization and cooling is introduced through this module. One panel is supplied for each injector. They are grouped and pipe-manifolded together for ease of installation.

Also includes the necessary panels per module. Complete assembly and testing, flow and pressure indication with regulators for chemical and atomizing air. Each panel will be mounted to a free-standing stainless steel base and a pipe-manifold assembled for easy flow accessibility.
*Typical Size: DM-4 – (2'W x 3.5'L x 6'H) Approximate weight: 300 lbs*
*Typical Size: DM-5 – (2'W x 5.5'L x 6'H) Approximate weight: 500 lbs*
**Reference FTI Drawings F-1 & F-6**

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY
(-Continued-)

### SLP3-I-FTL- INJECTORS

Installed at the appropriate elevation of the furnace, each injectors is appropriately sized and characterized for proper flows and pressures that are required to achieve the necessary NOx reductions. The injectors are made completely of 316L stainless steel. The nozzle tip will be 316L stainless steel supplied with a ceramic coating. The cooling shield is typically 3/4" Iconel tubing or 316 stainless steel with ceramic coating (.750" OD and .065" wall thickness). The inner atomization tube is typically 3/8" tubing with adapter to accept different injector tips, standard length is 2.5'.

Each assembly includes FTI air atomized injector, adapter for insertion adjustment, coupler to attach to boiler support, quick-connects and 6' long steel-braided flex hoses for both the chemical and atomizing air connections.
**Reference FTI Drawing G-1**

### SLP3-AR INJECTORS WITH AUTOMATIC RETRACT SYSTEM

The injector automatic retract device is an offset design and mounts on the standard/ recommended 1" Schedule 40 boiler penetration. The retract mechanism is an air-over-spring device of a hollow shaft design which operates and inserts the NOxOUT injector into the furnace when the atomizing/ cooling air is on. When the injector is fully inserted into the boiler a contact arm actuates a spool valve which starts the NOxOUT reagent flow to the injector. When required, the injector will automatically retract (using the compressed spring as the motive force) and chemical flow will be shut-off.

The advantages of the retract system include: complete automation and control room indication of the NOxOUT Injection System, improved system operation and chemical utilization, reduced manpower requirements, improved wear life of the injector, insurance of the presence of atomizing/ cooling air when the reagent starts to flow, reduced system operating costs by eliminating cooling air requirements for unused injector lances.

Each Injector Retract includes a specially designed 33" air-over-spring cylinder with non-rotating shaft, boiler penetration adapter flange (1" Schedule 40 MNPT), stainless steel chemical valve and actuator arm, injector position proximity switch, ceramic-coated shield extension, flex hoses, local control 3-way solenoid, safety guard and assembly of NOxOUT Injector and associated tubing into the auto-retract device.

An Injector Retract Local Panel is included for each retract system level to show local indication and act as a junction box to feed retract "inserted/ retracted" signals to the main remote control module. This panel will also be used to control the valve actuators that dictate the injector levels in-service.
**Reference FTI Drawing G-2**

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY
(-Continued-)

**RETRACT CONTROL PANEL**
An Injector Retract Control Panel is need for each retract system to provide local indication of the injector status and act as a junction box to feed retract "inserted/ retracted" signals to the main control module. This panel will also be used to control the valve actuators that dictate the injector levels in service.

**MULTIPLE NOZZLE LANCE (MNL), 26' Inserted Length**
The Multiple Nozzle Lance is designed to provide chemical coverage in locations where the standard wall-mounted lance cannot produce the necessary coverage. Each MNL is supplied with a retract mechanism to remove the lance from the boiler cavity when the lance is not in use, or in the event of a loss of cooling water flow, high cooling water temperature or loss of atomization air flow.

This lance is designed using the principle of air atomization and consists of pairs of nozzles that are spaced along the length of the lance to provide a fine chemical spray into the back pass flue gases. Nozzles are spaced at intervals along the length of the lance and may be altered in order to provide better chemical utilization and control of ammonia slip. The lance will require a distribution panel which will control the chemical mixture and air flows to the lance and a panel to monitor and control the cooling water flow and temperature as well as the retract mechanism.

The standard MNL will be inserted through an 8 - 10" diameter opening. Retract mechanisms are similar to soot blower retract mechanisms. These lances and retracts are custom designed for each application to provide the chemical coverage required as determined by the Process Engineering Department.
**Reference FTI Drawing G-17**

**MULTIPLE NOZZLE LANCE (MNL) DISTRIBUTION MODULES**
The Multiple Nozzle Lance Distribution Modules are placed prior to the Multi-Nozzle Lances and are used to control the injection rate of atomizing/cooling air, mixed chemical, and cooling water. Air and mixed chemical may be regulated at the module to produce the proper air/liquid mass ratios that produce the optimum NOx reduction.

Each Module is designed to control the injection rate of two (2) MNLs. Control of the MNL Distribution Module is achieved through the use of a local programmable logic controller. The system may be operated in local operation at the local control panel or may be operated in remote mode from the Master Control Module.

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY
(-Continued-)

The Module includes motor operated valves, piping, valves, pressure and flow regulators and indication, programmable logic controller, and complete assembly and testing. The system will control the flow.
**Reference FTI Drawing F-5**

### CONDENSATE PRESSURE CONTROL STATION

The condensate pressure control loop regulates the cooling water pressure for the MNLs in order to maintain the proper flowrate and temperature. The pressure loop maintains a sufficient cooling water pressure downstream of the MNLs and the regulator at the MNL Distribution Module is adjusted to maintain proper flow and temperature.
**Reference FTI Drawing J-8**

### AIR PRESSURE CONTROL STATION

The air pressure control loop regulates the air pressure for the MNLs in order to maintain the proper atomizing air pressure. The pressure control valve maintains a sufficient air pressure upstream of the MNLs and the regulator at the MNL Distribution Module.
**Similar to Reference FTI Drawing J-8**

### TEMPERATURE MONITORING SYSTEM

The temperature monitoring system supplied by Fuel Tech is an optical pyrometer designed to continuously monitor the furnace flue gas temperature. The temperature monitor senses the visible light from the ash particles to determine the flue gas temperature. Temperature readings are not biased by unit wall temperatures and can provide temperature readings for units firing coal, wood waste, municipal solid waste, refuse derived fuels, heavy oil or any other fuel which produce glowing particles during combustion.

The temperature sensed by the monitor will be utilized in determining the proper zone of injection for the NOxOUT process. By properly selecting the zone of injection based on flue gas temperature, the NOxOUT process can be optimized with regard to NOx reduction, chemical flows, and ammonia slip. This temperature control signal allows the Fuel Tech engineers to optimize the system operation and provide the best available SNCR system.

The temperature monitor will require the following utilities and connections in order to be installed and operate properly:

- 3" threaded pipe nipple extending 4-6 inches outside the boiler wall
- 110 VAC power
- 60 to 80 psig plant air
- Structural support of the unit (approximately 100 lbs)

**Reference FTI Drawing G-11/G-15**

## FUEL TECH EQUIPMENT SCOPE OF SUPPLY
(-Continued-)

**ENGINEERING:**

Fuel Tech will provide Project and Process Engineering and the following drawings and information:

- P&ID's
- Mechanical Drawings Include
  - General Arrangements and Module layout
  - Bill of Materials
  - Dead Weights and Sizes
- Electrical Drawings including:
  - Schematics
  - External Connection Diagrams (Field Terminations)
  - Electrical Bill of Materials
  - Logic Diagrams
- Interface Drawings
- Injector location Drawings and Modeling Report(s)
- Equipment and Instrument Data Sheets
- O&M Manuals

The Dilution Water, Injection Zone Metering, and Distribution Modules will be skid mounted with all equipment, piping, instruments, electrical and controls shop assembled. Installation by others will require interconnecting mechanical and electrical. The Dilution Water, Injection Zone Metering, and Distribution Modules must be located indoors for freeze protection. Size, weight and electrical requirements are specified on the drawings. All control devices require field installation.

**ENGINEERING SERVICES:**

- Process and Project Engineering
- Temperature and Species Mapping
- One Hundred (100) Mandays for Start Up, Optimization, and Training
- Operation and Maintenance Manuals (5)
- Three (3) Formal Drawing Submittals, including:
  1. For Approval Submittal
  2. Release for Construction Submittal
  3. As-Built Submittals

Any additional submittals required by Owner or Owner's Engineer shall be provided at an additional charge.

## SCOPE OF SUPPLY BY OTHERS

1. NOxOUT Reagent Storage Tank Foundation, Containment, and Reagent Offloading
2. Installation of Fuel Tech Equipment and Installation Management, including Interconnecting Piping and Wiring for FTI Supplied Equipment
3. MCC's, Motor Starters, and Motor Overloads for IZM's and DWP's
4. Programming of DCS Controls/Additional DCS Cabinets if Required
5. Compressors for Atomizing Air As Required
6. 3" Boiler Penetrations and Fittings for FTI Supplied MNL and 1" Boiler Penetrations and Fittings for FTI Supplied SNCR Injectors
7. Asbestos Removal.
8. Construction Permits and All Other Applicable Permits
9. Removal of Underground Obstructions and/or Contaminated Soil.
10. Utility Requirements In Accordance With Table 1. Assumes all injectors are in service and operating.
11. Reagent Chemical Supply.
12. NOx and Ammonia Monitoring Equipment.
13. Performance Testing.
14. Spare Parts

### TABLE 1 - ESTIMATED UTILITIES REQUIREMENTS

| Utility Description | QUANTITY PER UNIT |
|---|---|
| TOTAL DILUTION WATER, GPM (60 PSIG, 80°F), SNCR | 91 |
| TOTAL ATOMIZING AIR, SCFM (80 PSIG) | 938 |
| TOTAL INSTRUMENT AIR, SCFM | 45 |
| MNL COOLING WATER, CONDENSATE QUALITY, 150 PSIG INLET, < 100°F, (GPM) | 305 |
| AUXILIARY POWER, kWatts | 95(1) |

Notes:

1. No power or utilities have been included for reagent storage tanks.

## PRICING AND PAYMENT TERMS

**PRICE - $NO_X$OUT® SNCR SYSTEM:**

For the Project Engineering, Equipment, Testing, Startup, Optimization, and Training as defined for Midwest Generation Will County Station Unit #4 Fuel Tech quotes the firm price of:

**TERMS OF PAYMENT:**

10% Upon Receipt of signed Letter of Intent, Purchase Order or Contract, Whichever Occurs First, Between Fuel Tech, Inc. and Buyer.

40% Upon submittal of Drawings to the Buyer for Approval.

40% Upon Date of shipment of Equipment, or Thirty Days After Notification to Buyer that Equipment is Ready to Ship, whichever Occurs First.

10% After Successful Completion of Startup, or six (6) Months after Delivery of Equipment to Customer Site, whichever occurs first.

**EXHIBIT C3**

**FUEL TECH, INC. STANDARD TERMS and CONDITIONS**

These terms and conditions shall be part of the attached proposal and shall become part of the contract entered into between FUEL TECH, INC. (Fuel Tech), and the Buyer. Deviations from these terms and conditions must be agreed to in a writing signed by Fuel Tech and the Buyer. Fuel Tech hereby gives notice of its objection to any different or additional terms or conditions unless such different or additional terms or conditions are agreed to in a writing signed by Fuel Tech and Buyer.

1. TERMS OF PAYMENT:

   All invoices are payable net thirty (30) days from date of invoice. Buyer shall pay interest at the rate of ten percent (10%) per annum on all overdue amounts. Buyer shall pay all sales tax, use tax, excise tax, or other similar taxes.

2. DELAYS:

   If shipments are delayed by Buyer, payment shall be due on and warranty coverage shall begin to run from thirty days after the original shipment date specified in the contract or thirty (30) days after notification to Buyer that equipment is ready to ship, whichever is earlier. Risk of loss shall pass to Buyer at the time that equipment is identified, and any costs caused by such delay shall be borne by Buyer.

   If shipments are delayed by Buyer, Fuel Tech will ship the equipment no later than sixty (60) days after initial notification to the Buyer that the equipment is ready for shipment. Buyer agrees either (1) to provide Fuel Tech an appropriate "ship to" address and to accept delivery or (2) pay reasonable storage charges for the equipment beginning sixty (60) days after initial notification to Buyer that equipment is ready to ship.

3. PERFORMANCE GUARANTEE:

   Buyer warrants that the operating conditions of the Unit are those specified in the Process Design Table. Buyer is solely responsible for the accuracy of that operating condition information, and all performance guarantees and equipment warranties granted by Fuel Tech shall be void if that operating condition information is inaccurate or is not met. All performance guarantees and equipment warranties are conditioned on Buyer timely providing all of the equipment,

**EXHIBIT C3**
**FUEL TECH, INC. STANDARD TERMS AND CONDITIONS**
**(-CONTINUED-)**

materials, chemicals, utilities, and services that it has agreed to provide, on operating the Unit within the operating conditions specified in the Process Design Table, and on using reagent of license grade quality in the operation of the Unit.

4. EQUIPMENT WARRANTY:

Fuel Tech warrants that the equipment it provides shall be free from defects in design, workmanship, and material at the time the equipment is delivered and for a period of twelve (12) months after initial operation, or eighteen (18) months from shipment of equipment, whichever occurs first. Fuel Tech does not warrant wear parts such as injection tips, cooling shields, pump diaphragms, check valves, solenoids, pump impellers, pump wear rings, pump seals, valve packing, and valve seats.

All warranties made by the manufacturer of the equipment (if that manufacturer is any entity other than Fuel Tech) shall be assigned by Fuel Tech to the Buyer, if such assignment is permissible by law and contract. Warranty coverage starts at shipment of equipment or thirty (30) days after notification to Buyer that equipment is ready to ship.

5. DISCLAIMER OF WARRANTIES:

Fuel Tech warrants its equipment and the performance of its equipment solely in accordance with the equipment warranty and performance guarantee contained in this proposal and makes no other representations or warranties of any other kind, express or implied, by fact or by law. All warranties other than those specifically set forth in this proposal are expressly disclaimed. **FUEL TECH SPECIFICALLY DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, AND DISLCAIMS THE IMPLIED WARRANTY OF MERCHANTABILITY, THE IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, AND ANY OTHER IMPLIED WARRANTIES OF DESIGN, CAPACITY, OR PERFORMANCE RELATING TO THE EQUIPMENT.**

6. LIMITATION OF LIABILITY:

Buyer's sole remedy under the equipment warranty and the performance guarantee shall be to allow Fuel Tech, at Fuel Tech's option, either to repair, replace, or supplement the equipment to meet the performance guarantee, or, in the event that those options are not feasible, to remove the Equipment and refund the contract price to Buyer.

**EXHIBIT C3**

**FUEL TECH, INC. STANDARD TERMS AND CONDITIONS**
**(-CONTINUED-)**

NOTWITHSTANDING ANYTHING TO THE CONTRARY, FUEL TECH'S TOTAL LIMIT OF LIABILITY ON ANY CLAIM, WHETHER FOR BREACH OF CONTRACT, BREACH OF WARRANTY, TORT, NEGLIGENCE, STRICT LIABILITY, OR ANY OTHER LEGAL THEORY, FOR ANY LOSS OR DAMAGE ARISING OUT OF, OR CONNECTED TO, OR RESULTING FROM THIS AGREEMENT, INCLUDING WITHOUT LIMITATION AMOUNTS INCURRED BY FUEL TECH OR BUYER IN ATTEMPTING TO REPAIR, REPLACE, OR SUPPLEMENT THE EQUIPMENT OR MEET THE PERFORMANCE GUARANTEE, SHALL BE LIMITED TO THE CONTRACT PRICE TO BE PAID BY BUYER PURSUANT TO THE CONTRACT.

7. EXCLUSION OF CONSEQUENTIAL DAMAGES:

NOTWITHSTANDING ANYTHING TO THE CONTRARY, IN NO EVENT SHALL FUEL TECH BE LIABLE FOR ANY INDIRECT, CONSEQUENTIAL, INCIDENTAL, SPECIAL, OR PUNITIVE DAMAGES, INCLUDING BUT NOT LIMITED TO LOSS OF CAPITAL, LOSS OF REVENUES, LOSS OF PROFITS, LOSS OF ANTICIPATORY PROFITS, LOSS OF BUSINESS OPPORTUNITY, DAMAGE TO EQUIPMENT OR FACILITIES, COST OF SUBSTITUTE NOx REDUCTION SYSTEMS, DOWNTIME COSTS, GOVERNMENT FINES, OR CLAIMS OF CUSTOMERS, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

8. RESPONSIBILITY FOR THIRD PARTIES

Buyer shall at all times be responsible for the acts and omissions of its subcontractors and of any other third parties hired or retained or contracted by Buyer to perform work or provide equipment related to the system provided by Fuel Tech, including but not limited to third party design, systems integration, equipment tie-in, or process design changes. Fuel Tech shall have no responsibility for ensuring the accuracy of any such work or the performance of any equipment provided by subcontractors or third parties hired or retained or contracted by Buyer, and Buyer assumes all liability for any such work or equipment and for any failures in Fuel Tech's equipment caused by any such subcontractors or third parties hired or retained or contracted by Buyer. Buyer agrees to indemnify, hold harmless, and defend Fuel Tech from any claims, losses, damages, injuries, or failures caused by any such subcontractors or third parties.

## EXHIBIT C3

## FUEL TECH, INC. STANDARD TERMS AND CONDITIONS
(-CONTINUED-)

9. CONFIDENTIALITY:

Buyer agrees that it shall hold Confidential Information received from Fuel Tech in the strictest confidence, shall not use the Confidential Information for its own benefit except as necessary to fulfill the terms of the agreement between the parties, shall disclose the Confidential Information only to employees, agents, or representatives who have a need to know the Confidential Information, shall not disclose the Confidential Information to any third party, shall not copy the Confidential Information, shall not disassemble, decompile, or otherwise reverse engineer the Confidential Information and any inventions, processes, or products disclosed by Fuel Tech, and, in preventing disclosure of Confidential Information to third parties, shall use the same degree of care as for its own information of similar importance, but no less than reasonable care.

10. LICENSE AGREEMENT AND OTHER TERMS:

Sale is subject to agreement on other terms and conditions, including a Sale of Equipment with License Agreement.

11. INDEMNIFICATION:

Each Party shall defend, indemnify, and hold harmless the other Party and its employees, agents, and representatives from any claims, liabilities, lawsuits, costs, losses, or damages that arise out of or result from any negligent or willful acts or omissions of the indemnifying Party's employees, agents, or representatives. Where such claims, liabilities, lawsuits, costs, losses, or damages are the result of the joint or concurrent negligence or willful misconduct of the Parties or their respective agents, employees, representatives, subcontractors, or any third party, each Party's duty of indemnification shall be in the same proportion that the negligence or willful misconduct of such Party, its agents, employees, representatives, or subcontractors contributed thereto. The Party entitled to indemnity under this Agreement shall promptly notify the indemnifying Party of any indemnifiable claim, liability, lawsuit, cost, loss, or damage. The Party responsible for indemnification under this Agreement shall conduct and control the defense of the indemnified claim, liability, lawsuit, cost, loss, or damage. The Parties shall use their best efforts to cooperate in all aspects of the defense of any such claim, liability, lawsuit, cost, loss, or damage.

**EXHIBIT C3**

**FUEL TECH, INC. STANDARD TERMS AND CONDITIONS**
(-CONTINUED-)

12. FORCE MAJEURE

The Parties shall be excused from liability for delays in manufacture, delivery, or performance due to any events beyond the reasonable control of the Parties, including but not limited to acts of God, war, national defense requirements, riot, sabotage, governmental law, ordinance, rule, or regulation (whether valid or invalid), orders of injunction, explosion, strikes, concerted acts of workers, fire, flood, storm, failure of or accidents involving either Party's plant, or shortage of or inability to obtain necessary labor, raw materials, or transportation ("Force Majeure"). Any delay in the performance by either party under this Agreement shall be excused if and to the extent the delay is caused by the occurrence of a Force Majeure, provided that the affected party shall promptly give written notice to the other party of the occurrence of a Force Majeure, specifying the nature of the delay, and the probable extent of the delay, if determinable.

Following the receipt of any written notice of the occurrence of a Force Majeure, the parties shall immediately attempt to determine what fair and reasonable extension for the time of performance may be necessary. The parties agree to use reasonable commercial efforts to mitigate the effects of events of Force Majeure.

No liabilities of any party that arose before the occurrence of the Force Majeure event shall be excused except to the extent affected by such subsequent Force Majeure.

13. GOVERNING LAW

This Agreement shall be governed by and interpreted in accordance with the laws of the State of Illinois, excluding its choice of laws rules. The parties shall attempt to settle any disputes, controversies, or claims arising out of this Agreement through consultation and negotiation in good faith and in a spirit of mutual cooperation. If those attempts fail, then any dispute, controversy or claim shall be submitted first to a mutually acceptable neutral advisor for mediation. Neither party may unreasonably withhold acceptance of a neutral advisor. The selection of the neutral advisor must be made within forty-five (45) days after written notice by one party demanding mediation, and the mediation must be held within six months after the initial demand for it.

**EXHIBIT C3**

**FUEL TECH, INC. STANDARD TERMS AND CONDITIONS**
(-CONTINUED-)

By mutual agreement, however, the parties may postpone mediation until they have each completed some specified but limited discovery about the dispute, controversy, or claim. The cost of mediation shall be equally shared between the parties. Any dispute that the parties cannot resolve through mediation within six (6) months after the initial demand for it may then be submitted to a state or federal court of competent jurisdiction within the State of Illinois for resolution. The use of mediation shall not be construed (under such doctrines as laches, waiver, or estoppel) to have adversely affected any party's ability to pursue its legal remedies, and nothing in this provision shall prevent any party from resorting to judicial proceedings if good faith efforts to resolve a dispute under these procedures have been unsuccessful or interim resort to a court is necessary to prevent serious and irreparable injury to any party or others.

14. ENTIRE AGREEMENT

This Exhibit C3 and the Fuel Tech Proposal attached to it constitute the entire agreement between the parties and can be modified only in writing signed by authorized representatives of each of the parties.

## TYPICAL PROJECT SCHEDULE

### FUEL TECH, INC.
### UTILITY SNCR SYSTEM{tc \l1 "SECTION 10 : PROJECT SCHEDULE}

| EVENT | RESPONSIBILITY | WEEKS FROM ORDER DATE |
|---|---|---|
| Receipt of Order | CUSTOMER | 0 |
| Begin Temperature and Species Mapping | FUEL TECH | 2 - 4 Weeks |
| Complete Process Modeling | FUEL TECH | 10 |
| Begin Equipment Design | FUEL TECH | 2 |
| Submit Equipment Drawings[1] | FUEL TECH | 8 |
| Customer Drawing Comments Reviewed | CUSTOMER | 11 |
| Certified Drawings Issued | CUSTOMER | 15 |
| Begin Equipment Fabrication | FUEL TECH | 16 |
| Equipment Shipment | FUEL TECH | 31 |
| Equipment Delivery | FUEL TECH | 32 |
| Complete Equipment Installation | CUSTOMER | TBD |
| Begin Start-Up and Testing | FUEL TECH | 1-2 weeks one week after completion of installation |
| Begin Optimization | FUEL TECH | 2-4 weeks |
| Compliance Testing | CUSTOMER | TBD |

[1] General Arrangement and Piping & Instrumentation Diagrams

Schedule is typical for the system proposed, and is based on Customer having provided Fuel Tech all relevant design information. Drawing review is based on two (2) weeks. Accelerated schedule may require possible authorization to FUEL TECH for purchase of long lead items.

## FUEL TECH, INC.
## STANDARD NOxOUT® SYSTEM SPECIFICATIONS

**1 Scope**
This specification defines the requirements for the fabrication of a Fuel Tech, Inc. NOxOUT Selective Non-Catalytic Reduction System for the reduction of NOx Emissions.

**2 References**
Standard NOxOUT Process Description
Standard NOxOUT System Description
Standard NOxOUT Flow Diagram

**3 Codes and Standards**

| | |
|---|---|
| ANSI | American National Standards Institute |
| ASTM | American Society for Testing and Materials |
| ASME | American Society for Mechanical Engineers |
| AWS | American Welding Society |
| NEC | National Electrical Code |
| NEMA | National Electrical Manufacturers Association |

**4 Standard Equipment**
4.1 NOxOUT A Storage Tank

The NOxOUT A storage tank is a flat bottom, dome top vertical tank sized to hold ten days of projected chemical supply. In addition, the tank is supplied with a heating system to maintain 80 F during the worst case ambient temperature. Hold-down lugs are designed to local seismic, wind load, full and empty weights.

The storage tank is fabricated of Fiberglass Reinforced Polyester (FRP) in accordance with ASTM D3299, latest edition and coated on the inside with Premium Grade Vinyl Ester Resin as a corrosion barrier. Optional tank designs include RTP-1 for FRP tanks or API 650 S for a field erected stainless steel tank.

**FUEL TECH, INC.**
**STANDARD NOxOUT® SYSTEM SPECIFICATIONS**
(-CONTINUED-)

The following components are supplied with the standard tank:

- Heating pads, insulation and control panel with temperature and level display.
- Top and Side Man Ways
- Gooseneck Vent with screen
- Gusseted and flanged nozzles for tank-fill; circulation pump supply, and return; thermocouple; level transmitter; and spare.
- Internal suction pipe for pump suction nozzle and tank-fill nozzle.
- Thermowell, Thermocouple, and Level Transmitter
- Aluminum Ladder, safety cage and hand rail
- Hold-down Lugs (as determined by loading calculations)
- Lifting Lugs
- Stainless Steel Valves for outlet isolation, drain and return control

4.2 Skid Mounted Modules

4.2.1 Module Bases

All skid mounted equipment shall be mounted on 304 Stainless Steel bases that include lifting and hold-down lugs. Circulation and Metering Module bases shall include integral spill protection. Large bases shall incorporate fork lift tine pockets.

Distribution Module bases shall provide support for pipe and instruments required to control the air and NOxOUT® A flow to the injectors.

4.2.2 Control Architecture, Interfaces, and Panels

The Circulation Module and Metering Modules shall have Allen-Bradley Panel View Plus operator interfaces that are controlled by an Allen-Bradley Compact Logix Processor. Devices which are not hard wired to a control panel with the processor communicate via EtherNET and Remote I/O. Communication with the station's DCS, if required, is performed via EtherNET.

Panels requiring three phase power for motors or heaters shall have a single 480 VAC power connection. Fuel Tech, Inc. shall incorporate a transformer to provide 110 VAC and 24 VDC power to devices requiring power from the panel. If no motors or heaters are located on the equipment skid, a single 110 VAC power connection is required to the panel. Wiring on a module shall be performed by Fuel Tech, Inc. during fabrication to facilitate complete shop testing.

**FUEL TECH, INC.**
**STANDARD NOxOUT® SYSTEM SPECIFICATIONS**
(-CONTINUED-)

Typical Specifications:

- Enclosure: Hoffman Type – NEMA 4X – Stainless Steel
- Power Requirements: 480 Volt, 3 Phase, 15-30 Amp
- Conduit: Flexible Liquid Tight – Waterproof
- Wire: Minimum wire size shall be #14 AGA – Type THHN or XHHW (standard), SIS (optional adder) insulation or equal
- Fabrication: Per UL certified shop

4.2.3 Electric Components

Motors are purchased from approved vendors or vendors requested by the client. All motors shall be designed, constructed and tested by the motor manufacturer in accordance with the latest applicable NEMA, IEEE and ANSI Standards. AC Motors shall be TEFC, C-face, shall have a service factor of 1.15 at Class F temperature rise or 1.0 at Class B rise.

Electric valve actuators shall be sized for proper output torque and supplied with a NEMA 4X enclosure, thermal overload protector, visual position indication and a manual override.

Solenoid valves shall be supplied with an enclosure suitable for the applicable area (NEMA 4X standard), with F-Class coils (minimum) and with seals and disks made of Teflon.

The inline circulation heater shall consist of 304 Stainless Steel shell with 316 stainless steel elements welded to the flange, weather resistant terminal enclosure, 0-100 F SPST thermostat. The heater shall require 480 Volt, 3-Phase power.

Tank heating pads are supplied where required to keep the chemical above crystallization temperature due to ambient heat losses. Tank heating pads are installed under the tank insulation and are 500 W per pad and require 240 VAC (standard).

4.2.4 Piping, Tubing, Fittings and Valves

Pipe for NOxOUT, DI Water, Dilution Water (after strainers), and instrument air (on equipment modules) shall be welded schedule 40, 304 Stainless Steel. Pipe for Cooling Water shall be welded schedule 40 carbon steel. Unless otherwise noted, pipe flanges shall be rated for 150 psig.

**FUEL TECH, INC.**
**STANDARD NOxOUT® SYSTEM SPECIFICATIONS**
(-CONTINUED-)

Tubing shall be 304 Stainless Steel welded tubing with the following minimum wall thicknesses:

| | | |
|---|---|---|
| 1/4" = 0.035 | 1/2" = 0.049 | 1" = 0.065 |
| 3/8" = 0.035 | 3/4" = 0.065 | |

Fittings for tubing shall be compression type 316 Stainless Steel or welded Stainless Steel fittings. **Threaded (NPT) type fittings shall be avoided for Stainless Steel.**

Piping shall be supported using vibration dampening design clamps, made of corrosion resistant polyethylene.

The air and water lines components can be made of brass, bronze, carbon steel or cast iron.

All ball valves shall have a minimum operating pressure of 500 psi. Seal and seat materials shall be Teflon; other compatible materials may be substituted at Fuel Tech, Inc.'s discretion.

All accessories required for complete operating NOxOUT® System modules shall be supplied by Fuel Tech, Inc.

4.2.5 Instrumentation

Pressure gauges shall be of all stainless steel construction, with water-tight case and pulsation dampening. Diaphragm seals are to be supplied on chemical lines subject to crystallization. Isolation root valves are to be used with all gauges, except on the distribution modules.

A magnetic flow meter shall measure the NOxOUT® A, and dilution water flow rate. The flow meter shall have stainless steel internals and be equipped with a NEMA 4 enclosure, current output and flow rate display. Where low conductivity water or air flow measurement is required, a vortex shedding flow meter shall be used.

Injection Pressure and water flow shall be controlled through the use of a variable speed motor on a centrifugal pump and pressure transmitter.

Temperature indicators shall be stainless steel and supplied with thermowells. Thermocouples shall be Type E unless specified by the customer.

Tank level transmitters shall be a Differential Pressure type with a display.

**FUEL TECH, INC.**
**STANDARD NOxOUT® SYSTEM SPECIFICATIONS**
(-CONTINUED-)

4.2.6 Pumps

Chemical Circulation and Water Pressure Boost Pumps shall be stainless steel, close coupled vertical multi-stage centrifugal pumps with silicon carbide mechanical seals. Where pressure control is required, the pump speed shall be controlled with a combination of a pressure transmitter and a variable speed drive.

Metering Pumps shall be stainless steel, hydraulic-actuated diaphragm pumps. Pumps shall include complete turn-down capability, externally adjustable built-in relief valve, double ball check valves for both suction and discharge.

4.2.7 Injector Assemblies

The NOxOUT® injector lance shall distribute the atomized NOxOUT® A in the proper droplet size and spray pattern into the furnace at the locations required for the NOxOUT® process. Each injector requires 8-12 SCFM of air at 80 psig for atomizing the NOxOUT® A mixture and cooling the injector.

Each injector is supplied with six foot long flexible stainless steel hoses for connection to the installation tubing.

Furnace penetrations are provided by the client. For standard Injectors a 1" pipe nipple is welded to the webbing between boiler tubes. Fuel Tech, Inc. provides a female Cam-Lok fitting that attaches to the pipe nipple. The injectors have a adjustable male Cam-Lok fitting allowing the injectors to be inserted into the furnace and the furnace sealed.

**5 Optional Equipment**

Rotary Screw Air Compressor, complete with TEFC motor, Microprocessor Controller, Control Panel and all features to supply the quantity and quality of air for atomization and other NOxOUT® Equipment requirements.

Auto Retract injectors allow the injector to be automatically inserted and retraced from the furnace. When not in use, the injector is removed from the hostile environment and lasts longer.

**FUEL TECH, INC.**
**STANDARD NOxOUT® SYSTEM SPECIFICATIONS**
(-CONTINUED-)

## 6 Assembly and Testing

All equipment assembly and fabrication shops are selected and approved by Fuel Tech, Inc. Assemblers must follow all written Fuel Tech, Inc. specifications in the fabrication of equipment.

All equipment is pressure tested per ASME B31.1.

All equipment is functionally tested at the fabrication shop prior to shipping to the customer.