KARN FACILITY
DE Karn 1 and 2 Plant

MAINTENANCE AND MALFUNCTION ABATEMENT PLAN
SELECTIVE CATALYTIC REDUCTION (SCR)

April 2019
Revision 1

I. INTRODUCTION

A. SCOPE

This Maintenance and Malfunction Abatement Plan (MMAP) covers the monitoring, maintenance and operational requirements associated with the two (2) Selective Catalytic Reduction (SCR) Systems that control Nitrogen Oxide (NOx) emissions from the boilers at the DE Karn 1 & 2 Plants. This MMAP will assist in preventing, detecting and correcting malfunctions or equipment failures which could result in emissions exceeding applicable limitations.

B. PURPOSE

This plan has been developed to address the Michigan Department Environmental Quality – Air Quality Division (MDEQ-AQD) Air Pollution Control (APC) Part 9 requirements, specifically Rule 336.1911 (Rule 911) - Malfunction Abatement Plans, and the Karn Renewable Operating Permit (No. MI-ROP-B2840-2014c) for EU-KARN1 and EU-KARN2, Special Condition III.1, Process/Operational Restrictions requirement, which states in part that, "the permittee shall not operate the Unit unless a Malfunction Abatement Plan (MAP) as described in Rule 911(2), for the emission control equipment is implemented and maintained". Minimum requirements for Rule 911 compliance are listed in Part 1 (a, b, c) of Special Condition III.1.

Additionally, Special Condition IV.1, Design / Equipment Parameters, states the Unit shall not be operated unless the SCR is installed, maintained and operated in a satisfactory manner. Satisfactory manner includes operating and maintain the control device in accordance with an approved MAP.

II. SOURCE DESCRIPTION

Karn boiler No. 1 is a 2500 million BTU per hour dry bottom tangential coal fired boiler with fuel oil startup capabilities and supplemental co-firing for flame stabilization and mill outages. Nitrogen Oxide (NOx) emissions are controlled by the SCR. Sulfur Dioxide (SO_2) emissions are controlled by a Spray Dryer Absorber (SDA) system. The particulate emissions are controlled by a Low Pressure/High Volume Pulse Jet Fabric Filter (PJFF) System. Mercury (Hg) emissions are controlled on an as needed basis by injection of Activated Carbon.

Karn boiler No. 2 is a 2540 million BTU per hour dry bottom wall coal fired boiler with fuel oil startup capabilities and supplemental co-firing for flame stabilization and mill outages. Nitrogen Oxide (NOx) emissions are controlled by Low NOx Burners and SCR. Sulfur Dioxide (SO_2) emissions are controlled by a Spray Dryer Absorber (SDA) system. The particulate emissions are controlled by a Low Pressure/High Volume Pulse Jet Fabric Filter (PJFF) System. Mercury (Hg) emissions are controlled on an as needed basis by injection of Activated Carbon.

III. REGULATORY ANALYSIS

Karn Unit Nos. 1 and 2 each have a NOx emission rate limit of 0.080 lb/mmbtu (based on a 30-day rolling average). Each Unit utilizes Continuous Emissions Monitoring Systems (CEMS) for emission limit compliance monitoring.

IV. SELECTIVE CATALYTIC REDUCTION SYSTEM DESCRIPTION

One (1) dedicated SCR is installed at the exhaust outlet of each boiler at the Karn 1 and 2 Plant. The SCR reduces the concentration of NOx in the flue gas stream from each boiler. During the combustion process, the nitrogen that is present naturally in the coal, and the nitrogen and oxygen present in the combustion air combine to form NOx. As flue gas leaves the boiler, the reducing agent (ammonia vapor) is injected into the gas stream, prior to it entering the SCR through interconnecting ductwork. An inlet manifold evenly distributes the gas into the SCR reactor where porous ceramic catalyst containing vanadium pentoxide (V_2O_5) is held. The SCR catalyst is contained in steel modules and each SCR consists of one to four layers/levels of catalyst. In the presence of the catalyst, NOx will be selectively reduced by reacting with ammonia to form water and nitrogen (H_2O & N_2). Sonic horns are employed in the SCR reactor to prevent the catalyst from becoming fouled by fly ash accumulation. The SCR also has a catalyst outage protection system (COPS) that sends hot air into the reactor during unit outages for catalyst protection.

V. OPERATION OF THE SCR SYSTEM

A. OPERATION

1. Normal Operation

   The SCR is continuously operated at all times that the Unit it serves is in operation, consistent with technological limitations, manufacturers' specifications, good engineering and maintenance practices and good air pollution control practices for minimizing emissions.

2. SCR Bypass

   The SCR is equipped with a bypass that can be used when flue gas temperature is not adequate for safe operation, such as during a Unit start-up or malfunction. To ensure compliance with the applicable NOx emission rate, the duration of Unit start-up or malfunction is minimized to the extent possible.

B. SHUT-DOWN

1. Normal Shut-down

   The SCR shut-down is integrated into the boiler shut down sequence by Distributed Control System (DCS) initiation.

2. Unit Outages

During short unit outages, the SCR inlet and outlet dampers are closed and the catalyst outage protection system is engaged to prevent catalyst damage.

In the event of a longer unit outage, the SCR may be cooled for cleaning, inspection or maintenance activities. The COPS system would then be engaged once all maintenance activities are complete.

VI. SCR MONITORING PARAMETERS

The SCR operation is controlled and monitored from a central DCS. Online analyzers and alarms are an integral part of the system instrumentation. They warn Operators of impending problem situations. In some cases, the DCS will automatically switch operation to standby equipment. In all cases, alarms will be investigated and responded to accordingly. The following SCR parameters are monitored by plant personnel.

DE Karn Plant reserves the right to change the identified monitoring parameters and/or alarm set points based on manufacturer specifications, good engineering practices and operational experiences.

A. NOx Emission Rate

Non-certified NOx monitors are installed at the inlet and outlet of the SCR and a Part 75 certified NOx monitor is also installed on the stack. Operators shall monitor the SCR outlet and Stack NOx emission rate and ensure that it is below the emission rate limit specified in Section III of this MMAP.

B. Flue Gas Temperatures

Operators monitor flue gas temperature to ensure that SCR reactor temperatures are adequate. Temperatures greater than 800°F can sinter (melt) catalyst, reducing performance. Injecting ammonia below the minimum allowable ammonia injection flue gas temperature (MIT) can allow formation of ammonium salts that reduce catalyst performance and cause air preheater fouling. The MIT is dependent on the ammonia and sulfur concentrations and is generally specified by the catalyst vendor as a warranty condition.

C. SCR Reactor Differential Pressure

Differential pressure transmitters are installed at the inlet and outlet of the reactor to monitor for catalyst plugging. Operators monitor the reactor differential pressure for change in operating conditions. Acoustic (sonic) horns are employed to keep the ash suspended in the gas stream thereby minimizing the amount of ash that may settle on top of the catalyst. Operators and DCS logic control ensure the horns operate properly.

D. Acoustic Horn Air Pressure

Six acoustic (sonic) horns are installed on each SCR catalyst level. Operators ensure that adequate air pressure is established at each level, approximately 80 psig. System pressure at the main air receiver tank should be approx. 110 psig.

E. Ammonia Flow Rates

Ammonia flow is regulated via two ammonia flow control valves (per SCR) which are programmed to respond to changing unit load, inlet NOx and outlet NOx concentrations.

Operators monitor ammonia injection rates to ensure adequate NOx removal is being achieved.

F. Dilution Air System Temperature and Flowrate

There are two dilution air fans associated with a single air heater for each unit. Ammonia is mixed with heated air to ensure that its concentration in air stays outside of the flammability range (15% - 28%). Operators monitor the temperature and flowrate of dilution air, and ratio of air to ammonia. The expected heater outlet temperature is approx. 350° F. If outlet fan flowrate is too low, the system will automatically switch operation to the standby fan.

G. Ammonia Vaporization Pressure

Aqueous ammonia is vaporized with steam in one of two vaporizers that are common to Unit 1 and Unit 2. Operators monitor the ammonia vapor pressure which should be approx. 70 psig. The system will alarm at 85 psig and shutdown at 90 psig to prevent over-pressurization.

H. Vaporizer Steam Temperature and Pressure

Steam is supplied from Unit 1 or Unit 2 Cold Reheat into a desuperheated steam reducing station which regulates the pressure to approximately 150 psig while maintaining a temperature of approx. 366° F. Vaporizers are limited to a maximum steam pressure of 170 psig (for equipment protection).

I. Aqueous Ammonia Supply System

This system is comprised of four (4) 50,000 gallon storage tanks coupled with two forwarding pumps that feed aqueous ammonia to one of two vaporizers. The pumps typically operate at a discharge pressure of 85-90 psig. The gaseous ammonia and water vapor is then sent into each reactor duct via an ammonia flow control unit (AFCU) which meters the flow to ensure adequate NOx removal is achieved. Operators monitor tank levels to ensure adequate ammonia supply, and the system automatically moves to the standby tank if the level gets to 1.75 ft.

VII. MALFUNCTION ABATEMENT

During otherwise normal operation, an operator may experience some abnormal conditions that will result in the loss of NOx control and require immediate attention. Prompt response to alarms or abnormal conditions will reduce the risk of emission noncompliance and equipment damage. The SCR will be restored to normal operation as quickly as possible in response to any noted abnormal condition.

A. POTENTIAL MALFUNCTIONS

The following section identifies abnormal process conditions or operating problems, possible causes, and corrective actions to recover from the condition.

1. **Low NOx Removal Efficiency**

CAUSE	CORRECTIVE ACTION(S)
Insufficient ammonia injection	Verify no ammonia leaks, supply pressure is adequate and ammonia concentration is not too low. Correct as necessary. See Loss of Ammonia Feed Malfunction
Poor ammonia distribution	Conduct SCR tuning and adjust ammonia injection grid valves to improve distribution. Inspect/clean ammonia piping and injection nozzles during next outage of opportunity.
High Inlet NOx	Adjust combustion air and OFA at boiler as needed, conduct boiler tuning, verify instrument calibration, verify coal source, inspect/repair LNB, etc.
Catalyst deactivation	Conduct periodic catalyst testing and replace catalyst layers as needed during next outage of opportunity. Ammonia injection rates can be increased (to an extent) to improve NOx emission rates but boiler load may need to be reduced for compliance if deactivation is severe.
Catalyst plugging	Vacuum ash during next outage of opportunity. Severe pluggage may require catalyst replacement.
NOx analyzer malfunctioning	Inspect, calibrate and replace as necessary.

2. **High SCR Differential Pressure**

CAUSE	CORRECTIVE ACTION(S)
Malfunctioning pressure transmitter	Inspect, calibrate and replace as necessary.
Ash accumulation	Verify acoustic horn functionality. Vacuum ash during next outage of opportunity.
Acoustic horn(s) malfunctioning	Check supply air pressure and adjust if necessary. Verify horn sound. If bad, inspect sound generator and replace diaphragm as necessary. Inspect horn internal surfaces for ash buildup during outage and remove as needed.

3. **Loss of Ammonia Feed**

CAUSE	CORRECTIVE ACTION(S)
Transfer pump malfunction	Switch to redundant back-up pump. Troubleshoot primary and repair.
Low ammonia tank level	Switch to standby ammonia tank, align another back-up. Schedule fill of empty tank(s)
Frozen feed lines	Troubleshoot and correct issues with heat tracing of ammonia feed lines.
Ammonia shut-off valve tripped	Check ammonia/dilution air ratio. If high, ensure dilution air fan is running and/or increase air flow by opening dampers. Verify adequate flue gas temperature.

(table continued)

CAUSE	CORRECTIVE ACTION(S)
Loss of ammonia vaporization	Switch to back-up vaporizer, troubleshoot primary. Check steam temperature and desuperheating station; ensure proper line-up from operating boiler. Manage NOx emissions at reduced load.

4. **Loss of Dilution Air**

CAUSE	CORRECTIVE ACTION(S)
Dilution air fan tripped	System will automatically switch to back-up fan. Troubleshoot as necessary. Check inlet air filters and replace if necessary.
Electrical upset at dilution air heater	Inspect circuits and breakers and replace if necessary.

VIII. PREVENTATIVE AND PREDICTIVE MAINTENANCE

A. RESPONSIBLE PERSON(S) FOR PREVENTATIVE/PREDICTIVE MAINTENANCE

1. The System Engineer has designated responsibilities for determining and establishing predefined Maintenance Plans. As necessary, Maintenance Plans will be updated to include preventative/predictive maintenance and best practices resulting from malfunctions experienced.

2. The Maintenance Lead for the respective SCR equipment will ensure that the activities defined in the Maintenance Plans are carried out and documented on the schedule identified (based on frequency, interval, manufacturer / engineering recommendations, etc.) during scheduled periodic outages of adequate length.

   The SCR Maintenance Plans include the following inspections, which will be conducted during scheduled periodic outages of adequate length. The inspection results and maintenance activities/corrective actions will be documented and maintained electronically.

   Scheduled Periodic Outage Inspections:

   a. Check for signs of corrosion, moisture or in-leakage to the SCR Reactor and associated ductwork.

   b. Inspect associated man way doors / gaskets, dampers and expansion joints. Repair / replace as necessary.

   c. Inspect all catalyst banks for ash accumulation and plugging. Estimate % plugged and document. Vacuum ash as necessary.

   d. Inspect all associated ductwork, ammonia injection grid nozzles, acoustic horns and seal air piping for ash accumulation and plugging. Clean out / repair as necessary.

e. Remove catalyst samples for analysis of catalytic potential, an indicator of performance. Replace catalyst banks as required to ensure continued emission limit compliance.

f. Clean and inspect dilution air fans / heater and repair as necessary.

g. Inspect and repair as necessary large particle ash screens.

B. CRITICAL SPARE PARTS

The Equipment Reliability System Engineer will identify the necessary spare parts to be maintained in stock for quick replacement.

IX. RECORD KEEPING

A. MAINTENANCE

1. All maintenance activities (including preventative/predictive maintenance and maintenance related to malfunctions) related to the SCR system at the Karn 1 and 2 Plant will be documented electronically and maintained for a period of not less than five years. If some activities occur at frequencies of greater than five year intervals, the history will be extended for those activities such that as a minimum the last maintenance activity performed is retained.

2. All appropriate vendor information, as well as operations and maintenance (O&M) manuals, shall be maintained for reference and training. These documents will also be referenced for supply parts and proper maintenance practices. This information shall be maintained for the life of the equipment.

3. Malfunctions of the control equipment that is subject to compliance reporting shall be documented in the appropriate log.

B. OPERATIONS

1. Responses to critical alarms and corrective actions will be documented in electronic logs. Additionally, Operators should log the date and time of event and corrective action, applicable notifications / work orders, and if the SCR was limited or did not adhere to the Unit's operating procedures.