Preventive Maintenance and Malfunction Abatement Plan

Marquette Energy Center
Engine Units 1, 2, and 3

Project No. 190482
Revised June 25, 2019

Fishbeck, Thompson, Carr & Huber, Inc.
engineers | scientists | architects | constructors

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Marquette Energy Center
Engine Units 1, 2, and 3

Prepared For:
Marquette Board of Light & Power
Marquette Energy Center
Marquette, Michigan

Revised June 25, 2019
Project No. 190482

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1.0 Introduction

Marquette Board of Power & Light (MBLP) is a municipal electric utility serving approximately 17,000 customers in Marquette County, Michigan. This Preventive Maintenance and Malfunction Abatement Plan (PM/MAP) has been prepared for MBLP to comply with PTI 204-15A for the Marquette Energy Center (MEC). The PTI requires that MBLP adopt a PM/MAP within 90 days of permit issuance, or before June 27, 2019. Section 2.0 of this PM/MAP provides a source description; Section 3.0 presents a description of the air pollution control equipment; Section 4.0 includes the emission limits and describes malfunctions, and Section 5.0 outlines Rule 911 and provides a list of supervisor personnel associated with implementing this PM/MAP. Section 6.0 describes the PM Program and includes expected operating parameters and corrective procedures. Section 7.0 includes a list of spare parts; Section 8.0 includes information on estimating emissions, and Section 9.0 describes the requirements for reporting under Rule 912.

It should be noted that this PM/MAP meets the requirements of 40 CFR 60.4211(d) as well.

2.0 Source Description

MEC operates three Wärtsilä 18V50DF dual fuel-fired reciprocating internal combustion engines. Each is rated at approximately 17 MW and 173 MMBtu/hr when firing natural gas, or 154 MMBtu/hr when firing light fuel oil (LFO) or diesel fuel. MBLP intends to operate each engine base-loaded to provide electricity to MBLP customers. Each is equipped with SCR to reduce NO_X emissions and catalytic oxidation to reduce CO and VOC emissions. Collectively, MEC refers to this system as the *SCR+Oxi System*. The engines use primarily natural gas as fuel, though they are capable of firing LFO for 6,000 hr/yr total for the three engines.

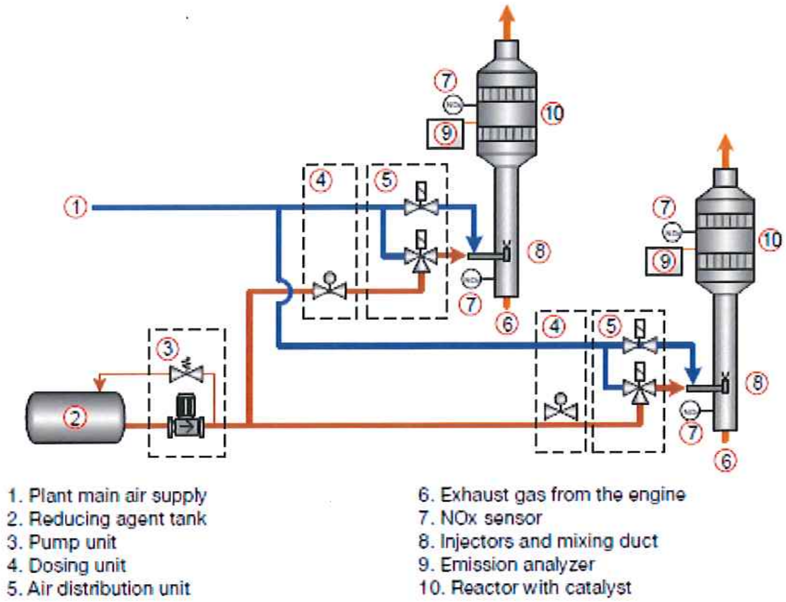
The Wärtsilä dual-fuel engines are unique because they have two different injection systems. A *micro-pilot injection system* is used when the engine is burning natural gas; the micro-pilot system allows a very small amount of fuel oil to be injected into the combustion chamber to ignite the natural gas. This amount makes it possible to meet very stringent emission regulations, which would not be possible if a normal injection system were used. A conventional injection system is used when the engine is running on LFO. Fuel flexibility and high efficiency are the main advantages of the dual-fuel technology. The Wärtsilä 18V50DF engine model has demonstrated an efficiency of more than 48%.

Three separate reciprocating engine-generator trains will operate in parallel within the engine hall/power block. The reciprocating engine subsystems include the engine, inlet air filtration, reciprocating engine, generator, and instrumentation. The reciprocating engine is comprised of cylinder block, valves, pistons, connecting rods, and a crankshaft. It is very similar to a conventional automobile engine, only larger. Each reciprocating engine contains 18 cylinders, pistons, and connecting rods, arrayed in V-formation. Reciprocating engine control and instrumentation will cover the engine governing system, and the protective system.

Thermal energy is produced in the reciprocating engines through the combustion of natural gas, which is converted into mechanical energy required to drive the crank shaft and electric generators. The generator sets will be equipped with the following required systems to provide safe and reliable operation:

- Natural gas and LFO fuel systems
- Lubricating oil system
- Compressed air systems
- Cooling system
- Intake air and exhaust gas systems
- Emission control system
- Fire detection and protection system
- Gas leakage detection system
- Oily water collection system
- Engine generator control and protection system

Figure 1 – SCR+Oxi System



Monitoring the inlet and outlet temperature to/from the reactor and the pressure drop over the reactor is essential for the proper operation of the system. The exhaust temperature is measured in the inlet and outlet of the reactor and the pressure drop is measured over all catalyst elements as well as over the oxidation catalyst elements. The reactor and the auxiliary units are available in different sizes, to serve different engine types, cylinder configurations, and emission abatement requirements. In multi-engine installations, the reducing agent pump and the control unit are shared by several engines, while the dosing units are engine-specific. The reagent dosing amount is fine-tuned with a closed loop NO_X controller. The NO_X controller uses another NO_X measurement as feedback. This feedback signal is provided by the analyzer that measures the NO_X emissions in the middle of the reactor (after the SCR elements and before the oxidation catalyst elements). This measurement value may differ from the final NO_X emission level at the outlet of the reactor. Neither NO_X measurement is performed using NO_X measurement of CEMS quality. If any of the measurement analyzers for the reagent or NO_X control fail, the system will fall back to a *limp mode*. As a result, the system will not be able to compare measurements before and after the reactor. The analyzer can indicate a fault mode if the sample cooler is not working properly, if both NO_X cells are disconnected, or have too high a zero point. If the analyzer alarms for any of these potential failure modes, the feedback control will be turned off and a preset correction factor will be used to meter urea until the measurement analyzers are serviced. If the analyzer alarms for failure, it means that it is incapable of measuring NO_X reliably or at all.

Oxidation catalyst layers for the abatement of carbon monoxide and unburned hydrocarbons are located after the SCR catalyst layers. The oxidation catalyst consists of a substrate to which one or several noble metals are added as catalytically active material. The oxidation reactions take place on the surface of the catalytically active material and utilize the excess of oxygen already present in the flue gas.

Catalytic oxidation converts carbon monoxide and VOCs to carbon dioxide and water by the following reaction:

$CO + ½\ O_2 \rightarrow CO_2$

$CO + ½\ O_2 \rightarrow CO_2$

$C_mH_n + (m+1/4n)\ O_2 + ½\ O_2 \rightarrow mCO_2 + 1/2nH_20$

$C_mH_nO + (m+1/4n)\ O_2 - ½\ O_2 \rightarrow mCO_2 + 1/2nH_20$

The oxidation catalyst requires no consumable reagent and produces no waste effluents. The catalyst elements are installed in the same reactor.

Following is a list of malfunction events covered by this Plan:

- Failure of the emission control systems that results in emissions exceeding the allowed rate contained in the MEC PTI and ROP. This will be detected through monitoring of operating parameters associated with the air pollution control equipment to ensure its proper operation.
- Failure of emission control system components (e.g., pump failure) monitoring equipment (such as equipment used for measuring the pressure drop across the catalyst), and data acquisition equipment to demonstrate compliance with emission limits. It should be noted that MEC maintains full back-up components (e.g., pumps) for critical systems (i.e., the urea injection system).
- An unexpected sudden and unavoidable failure of engine control equipment or monitoring equipment

During engine operation, the operators have been instructed to pay attention to indications of problems in the system including:

- Leakage
- Smoke
- Excessive vibration
- Abnormal sounds or odors

4.2 NSPS Requirements for Operating Engines Properly

MEC is required to operate the engine control equipment properly to ensure compliance with emission limits. In addition, 40 CFR Part 60.4211, requires MEC to define equipment operating parameters and their correct ranges for monitoring to ensure compliance. MEC monitors:

- Pressure drop over the reactors
- Reactor inlet/outlet temperature
- Urea injection
- NO_X feedback control
- Engine load

Using emissions testing and manufacturer's recommendations, MEC has identified acceptable ranges for these operating parameters which depend on engine load. While MEC operates add-on control equipment to lower NO_X emissions (as described in Section 3.0), MEC does not operate add-on control equipment for PM.

PM in engine exhaust results primarily from partially oxidized fuel (most often LFO), lubricating oil in the exhaust or sulfates formed when sulfur in fuel is oxidized.

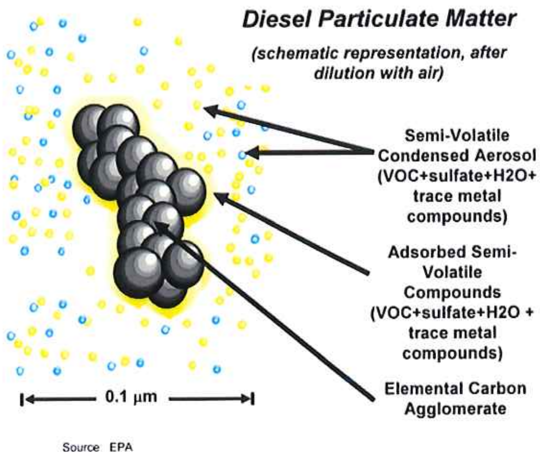


Figure 2 – Formation of PM in Engine Exhaust

Table 3 contains the titles and responsibilities of the responsible personnel, for purposes of this PM/MAP

Table 3 – Responsible Personnel

Position	Responsibility
Director of Operations and Maintenance	Overall responsibility for engine operation, corrective actions, and malfunction response
Maintenance/Engineering Services Manager	Preventative maintenance inspections and repairs
MEC Operators	Pollution control equipment monitoring and oversight
Environmental Compliance	Monitoring monthly emissions estimates, ensuring emission testing and reporting is completed
Outside Contractors (as necessary)	Calibration, repairs, and maintenance of equipment instrumentation

6.0 Preventive Maintenance Program, Operational Variables and Corrective Procedures

Preventive maintenance will include equipment inspections, scheduled replacement of parts, and maintaining an inventory of critical spare parts. The facility's Inspection and Maintenance (I&M) database system tracks and maintains records of each preventive maintenance action and/or repair completed and will track maintenance and repairs performed. This system was established by the engine manufacturer and then loaded into the MEC PM System.

Equipment inspections generally fall under two categories:

- Inspections that take place while the engines are operating
- Less frequent inspections that take place during an engine outage

I&M that occurs during engine operation is typically on a more frequent basis than I&M that occurs when the engine is not operating (shutdown or outage). The frequency and scope of these inspections will depend on the manufacturer recommendations; however, will be adjusted based on operator experience.

MEC will utilize internal resources, as well as outside vendors, to conduct maintenance, repairs, and calibration, as necessary.

6.2 Weekly Maintenance Schedule (or Upon System Startup)

1. The complete Engine Start-up/Weekly Checklist included in Appendix 1. Conducted during weeks when the engine is operating.
2. Maintain a record of the observation(s) and service(s) performed.

6.3 Monthly Maintenance Schedule

1. Inspect and maintain the dosing and reagent system pumps.
2. Inspect and maintain the dosing unit air filters.
3. Perform NO_XBox System maintenance.
4. Calibrate the measurement cells in the NO_X analyzer.
5. Inspect and maintain the temperature and differential pressure transmitters associated with the SCR+Oxi System.
6. Maintain a record of the observation(s) and service(s) performed.

6.4 Annual Routine Maintenance

1. Inspect and maintain the compressed air system associated with the SCR+Oxi System.
2. Inspect and maintain the atomizing lance associated with the SCR+Oxi System.
3. Inspect and maintain the reducing agent filters.
4. Inspect and maintain the compressed air filter associated with the dosing unit.
5. Change reducing agent gear box oil.
6. Replace NO_X sensors.
7. Inspect and maintain the air distribution unit.
8. Inspect and maintain NO_XBox System analyzers.
9. Calibrate the fuel meters, the pressure and temperature transmitters, and the transducers associated with the SCR+Oxi System.
10. Inspect and maintain the catalyst.
11. Maintain a record of the observation(s) and service(s) performed.

6.5 Corrective Action

If a malfunction occurs which causes, or may cause, excess emissions during engine operations, the equipment causing the potential excess emission rate will be evaluated – as soon as practicable in accordance with safe operating procedures – to determine the proper procedure to correct the issue or determine that the malfunction will not cause excess emissions. In some cases, a faulty signal to the control panel may represent a false alarm. In that case, the electronic tracking system will be repaired and the operator will manually record readings at least once per day until repairs have been completed. Determine if the engine can continue to operate within compliance of the limitations specified in the MEC's PTI and/or ROP. If not, action shall be taken to correct the issue in accordance with safe operating procedures.

- Notify the appropriate staff of any issues that occur and/or if there are any questions regarding compliance or action(s) which should be taken to correct the issue.
- If the issue is one that calls for immediate corrective action, contact any one of the individuals listed in Section 5.0, Table 2.

7.0 Major Parts Kept Onsite for Quick Replacement

Following is a list of general spare parts kept onsite facilitating quick repairs and maintenance on the SCR+Oxi System. A detailed list, including a description and part number for each, is kept at MEC for ordering purposes.

Table 6 – Parts Kept Onsite

Equipment	Replacement Parts
Reducing Agent Pump	Spare pump, stator, flexible joint seals, rotor, joint parts, shaft seals, axle shift seal, filter cartridge, sealing ring
Dosing Unit	Air filter element, sealing O-rings
Reducing Agent Injection System	Atomizing lance with 1 nozzle tip, additional nozzle tip
NO_xBox	NO_X sensors (4), NO_X calibration gas, air inlet filter (2), peristaltic pump, measurement cell (4)
Catalysts	Gaskets, sealing cord for service hatches, sealing strip

8.0 Emissions Tracking and Monitoring

MBLP must comply with a site-wide NO_X limit of 222 tons per 12-month rolling total by tracking NO_X emissions from the engines. Emission factors are obtained by engineering testing, performance testing, or compliance testing Emission factors, developed from the most recent testing, are provided in Appendices 2 and 3.

Emissions are calculated using emission factors multiplied by the fuel throughput in conjunction with its heating value.

NO_X emissions (tons/12 months) = (fuel consumption - gal/mo or MMscf/mo) x (heat input - Btu/gal or Btu/scf) x (emission factor - lb/MMBtu) x (ton/2,000 lb)

The ROP also requires tracking of VOC and individual HAP (formaldehyde) emissions. Calculations for VOCs and individual HAPs are performed in similar matter with a spread sheet maintained at the site.

9.0 Reporting Malfunctions and Abnormal Conditions

Michigan Rules 912(2)-(5) require facilities to report of certain abnormal conditions, start-up, shutdown, or malfunctions associated with process and/or emission control systems subject to air quality requirements.

Michigan Rule 912(2) addresses reporting requirements for sources releasing emissions of HAPs and/or TACs in excess of applicable limitations for one hour or more. The requirement reads:

> *The owner or operator of a source, process, or process equipment shall provide notice of an abnormal condition, start-up, shutdown, or a malfunction that results in emissions of a hazardous air pollutant which continue for more than 1 hour in excess of any applicable standard or limitation established by the clean air act or the emissions of a toxic air contaminant which continue for more than 1 hour in excess of an emission standard established by a rule promulgated under the air pollution act or an emission limitation specified in a permit issued or order entered under the air pollution act.*

Appendix 1

Appendix 1 - Start-up Checklist (Performed at Leat Once per Week)
Marquette Board of Light & Power
Marquette Energy Center, Marquette, Michigan

Checklist Completed by: ____________________
Date: ____________________

Check Unit #1 - PAAE266676 Wartsila 18V50DF	Value	Units	Expected Range	Comments
Engine Load		kW	4,000 - 17,700	
Pressure Drop Over the Reactor		lbf/ft^2	0 - 53	
Reactor Inlet Temperature		°F	570 to 850	
Reactor Outlet Temperature		°F	570 to 850	
Urea Injection Rate		gal/hr	0-14 (gas) 0-121 (LFO)	

Check Unit #2 - PAAE266677 Wartsila 18V50DF	Value	Units	Expected Range	Comments
Engine Load		kW	4,000 - 17,700	
Pressure Drop Over the Reactor		lbf/ft^2	0 - 53	
Reactor Inlet Temperature		°F	570 to 850	
Reactor Outlet Temperature		°F	570 to 850	
Urea Injection Rate		gal/hr	0-14 (gas) 0-121 (LFO)	

Check Unit #3 - PAAE266678 Wartsila 18V50DF	Value	Units	Expected Range	Comments
Engine Load		kW	4,000 - 17,700	
Pressure Drop Over the Reactor		lbf/ft^2	0 - 53	
Reactor Inlet Temperature		°F	570 to 850	
Reactor Outlet Temperature		°F	570 to 850	
Urea Injection Rate		gal/hr	0-14 (gas) 0-121 (LFO)	

Notes:

* Operation outside of the expected range may not be problemeatic - it does merit investigation. In some cases, MEC may adjust the ranges

Appendix 1 - Start-up Checklist (Performed at Leat Once per Week)
Marquette Board of Light & Power
Marquette Energy Center, Marquette, Michigan

Checklist Completed by: ______________________
Date: ______________________

Check	Emissions Control System Manual 3C 12	Value/Checked	Expected Range	Comments
Inspect Reducing Agent Related Pipes and Instrumentation				
a. Inspect the pipe for leaks, insulation damage, broken or loose flanges, etc.	wca3698			
b. Operate valves and grease exposed moving parts as necessary				
c. Check all electrical connections for insulation damage or loose contacts				
d. Verify that all automatic equipment and instrumentation is operating correctly.				
Check the Reducing Agent Supply				
a. Check the level in the reducing agent tank		%	25 - 100	
b. Check the reducing agent temperature		°F	41 - 95	
Inspect the Reducing Agent Pump Unit				
a. Check the pump for abnormal vibration or noise.	wca3445			
b. Check the pump inlet and outlet pressure.		psi	(Inlet) -7.25 - 61 (Outlet) 43.5 - 145	
c. Fill the barrier fluid cup with water if necessary	wca3717			
d. Check the output frequency or the pump control signal of the frequency converter.		Hz	0 - 60 Hz	
e. Check the electrical cabinet cooling and the dosing unit air filters, clean dust/deposits if necessary.	wca3717 wca3719 3C 12 2-19			
f. Check the heat tracing cabinet for proper operation (seasonal) and setpoints.	wca3717			
Check the Operation of the Emission Analyzers (Engine 1,2,3)				
a. Check that the flow through the flow meters is stable.	wca3443 3C 12 2-35			
b. Check the operation of the main sample pump by checking that gas flows out of the exhaust drain when the analyzer is measuring.	wca3700 3C 12 2-35			
c. Check that the measurements from the analyzer are realistic and that the measurement cells are showing similar values. (NO Cell 1 & 2 Raw / CO Cell Raw)	wca3700			
d. Check for moisture in the filters.	wca3700			
e. Check that the sample selection valve is tight.	wca3700 3C 12 2-35			
f. Check the operation of the peristaltic pump and tube inside. (Remove cover)	wca3700 3C 12 2-41			

Appendix 2

Appendix 2 - Engine Test Summary and Emission Factor Development (Natural Gas)
Marquette Board of Light & Power
Marquette Energy Center, Marquette, Michigan

		Engine One			
	Emission Limit	Run One	Run Two	Run Three	Average
Active Power (kW)		17,006	17,007	17,011	17,008
Average hp		22,743	22,793	22,761	22,766
NOx Concentration (@15% O_2)	**82**	1.8	1.1	1	1.3
NOx (lb/hr)	**3.3**	1.0	0.6	0.6	0.7
NOx (g/hp-hr)	**1.0**	0.020	0.012	0.011	0.014
NOx Emission Factor (lb/MMBtu)		0.0071	0.0043	0.0043	0.0052
CO Concentration (@15% O_2)	**270**	0.9	0.6	0.6	0.7
CO (lb/hr)	**5.0**	0.3	0.2	0.2	0.2
CO (g/hp-hr)	**2.0**	0.006	0.004	0.004	0.005
CO Emission Factor (lb/MMBtu)		0.0021	0.0014		0.0018
VOC Concentration (@15% O_2)	**60**	3.9	4.7	1.2	3.3
VOCs (lb/hr)	**16.5**	2	2.4	0.7	1.7
VOCs (g/hp-hr)	**0.7**	0.040	0.049	0.013	0.03
VOCs Emission Factor (lb/MMBtu)		0.0142	0.0172		0.0157
Formaldehyde Concentration		0.9	1.0	1.0	1.0
Formaldehyde (lb/hr)		0.19	0.22	0.22	0.21
Formaldehyde (g/hp-hr)		0.004	0.004	0.004	0.004
Formaldehyde (lb/MMBtu)		0.0013	0.0016	0.002	0.00
Fuel Use (lb/hr)		6226	6173	6216	6205.14
Fuel Use (scf/hr)		138,355	137,186	138,135	137,892
Heat Input (MMBtu/hr)		141.122	139.929	140.898	140.650
Reagent Flowrate (gal/hr)		9	9	9	9.30
Reactor Inlet Temperature (°F)		763	764	764	763.59
Reactor Outlet Temperature (°F)		770	772	773	771.59
Temperature Differential (°F)		7	8	9	8.00
Pressure Differential (lbf/ft^2)		20	21	21	20.56
Heat Rate (Btu/kW-hr)		8299	8228	8283	8269.78
Brake-specific fuel consumption (Btu/hp-hr)		6205	6139	6190	6178.18

Density of natural gas is 0.045 lb/scf
Heating value of natural gas is 1,020 Btu/scf

	Run One	Run Two	Run Three
Fuel Oil for Ignition	29.14194817	121.1921231	41.64942739
Heat Input from Ignition (MMBtu/hr)	4.050730796	16.84570511	5.789270408

19,300 Btu/lb
139,000 Btu/gallon

Appendix 3

Appendix 3 - Engine Test Summary and Emission Factor Development (LFO)

Marquette Board of Light & Power

Marquette Energy Center, Marquette, Michigan

	Emission Limit	Engine One
Active Power (kW)		17,011
Average hp		22,762
NOx Concentration (@15% O_2)		10.3
NOx (lb/hr)	**21**	5.8
NOx (g/hp-hr)	**2.58 g/kW-hr**	0.116
NOx Emission Factor (lb/MMBtu)		0.0425
CO Concentration (@15% O_2)		0.6
CO (lb/hr)		0.2
CO (g/hp-hr)		0.004
CO Emission Factor (lb/MMBtu)		0.0015
PM Concentration (gr/dscf)		0.0016
PM (lb/hr)		0.7880
PM (g/kW-hr)	**0.15 g/kW-hr**	0.0210
PM Emission Factor (lb/MMBtu)		0.0058
VOC Concentration (@15% O_2)		0.1
VOC (lb/hr)		0.0000
VOC (g/hp-hr)		0.001
VOC (lbMMtu)		0.0000
Fuel Use (lb/hr)		7065
Fuel Use (gal/hr)		981
Heat Input (MMBtu/hr)		136
Reagent Flowrate (gal/hr)		102
Reactor Inlet Temperature (°F)		663
Reactor Outlet Temperature (°F)		702
Temperature Differentual (°F)		39
Pressure Differential (lbf/ft^2)		21
Heat Rate (btu/kW-hr)		8015
Brake-specific fuel consumption (btu/hp-hr)		5,990

Density of natural gas is 0.045 lb/scf

Heating value of natural gas is 1,020 Btu/scf

19,300 Btu/lb

139,000 Btu/gallon

Appendix 4

ENVIRONMENTAL RELEASE REPORTING FORM

For internal use only.

To be completed by the Environmental Engineer

Date ______________ Time of Report ______________ Reported By ______________________

Location of Incident ____

Type of Incident ☐ Spill/Release ☐ Fire ☐ Explosion ☐ Other

Time Incident was Detected ______________ a.m./p.m. Duration of Event ______________

Name of Material(s) Released ____

Regulatory Status of Released Material: ☐ Michigan Critical Material ☐ Act 451, Part 31 Polluting Material

☐ Oil ☐ RCRA ☐ CERCLA ☐ EPCRA/SARA

Amount Released ____________________ (lbs) RQ? ☐ Yes ☐ No

Container Type ☐ Drum ☐ UST ☐ AST ☐ Other ______________________

Release Characteristics Color ____________ Odor ______________ Other ______________

Release Entering ☐ Drains ☐ Soil ☐ Surface Water ☐ Air Other ______________

Weather Conditions Precipitation ____________ Wind Direction/Speed ______________

Company Response Personnel at Scene ____

Outside Response Personnel at Scene ☐ Spill Contractor(s) ☐ Fire Department

☐ Regulatory ________________ Governmental ________________________

☐ Other ____

Injuries? ☐ No ☐ Yes (type of injuries) ____

Site or Building Evacuation? ☐ No ☐ Yes

Agencies Notified

☐ MDEQ*	Date ____________	Time ____________	Initials ____________
☐ Local Governmental Depts.	Date ____________	Time ____________	Initials ____________
☐ PEAS Hotline	Date ____________	Time ____________	Initials ____________
☐ EPA Response Center	Date ____________	Time ____________	Initials ____________
☐ UST Release Hotline	Date ____________	Time ____________	Initials ____________

**Written report must be filed with the MDEQ within ten (10) days.*