Operation and Maintenance Manual
ADCAT™ Oxidation Catalyst for CO and VOC

Manufactured By:
EmeraChem, LLC
1729 Louisville Dr.
Knoxville, TN 37921
Tel.: 865.246.3000
Fax: 865.246.3001
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## INDEX OF TERMS

**ADCAT™ CO** - EmeraChem’s proprietary non-selective catalytic reduction product for removing NOx/CO/VOC

**Catalyst** - A substance that changes the rate of a chemical reaction but emerges from the process unchanged

**CO** – Carbon monoxide

**CO₂** – Carbon dioxide

**CPSI** – Cells per square inch, the measure of cell density

**DRE** – Destruction and removal efficiency, expressed as a percent.

**EGO** – Exhaust gas oxygen (analyzer)

**Module** – A catalyst element; a canister containing catalyzed metal substrate.

**NMNEHC** – Non-methane, non-ethane hydrocarbons; part of the regulatory definition of VOCs.

**NOₓ** - Nitrogen Oxide, composed predominantly of NO and NO₂, and includes other compounds.

**O₂** – Oxygen

**PPM** – Parts per million; a measure of concentration.

**PPMVD** – Parts per million by volume, dry.

**PPMVDC** – Parts per million by volume, dry, corrected to a specific oxygen concentration.

**SCFH** – Standard cubic feet per hour

**SO₂** – Sulfur dioxide

**SO₃** – Sulfur trioxide

**Space Velocity** – A measure of the amount of exhaust gas one cubic foot of catalyst can process to achieve a specific level of performance for a specific compound. Calculated by dividing the volumetric flow rate of exhaust gas (in
standard cubic feet per hour) by the number of cubic feet of catalyst; expressed as 1/hr.

**Substrate** – A high temperature, metal, multi-cellular monolithic structure onto which the catalyst coating is applied.

**UHC** – Unburned hydrocarbons.

**VOC** – Volatile organic compounds.
1. INTRODUCTION
Thank you for purchasing EmeraChem's field proven ADCAT™ Oxidation catalyst for reduction of CO and VOCs. This document provides operating guidelines for the catalyst system, including an overview of the catalytic process, installation of the catalyst, system operation, and catalyst maintenance. Instrumentation needed to operate and maintain the ADCAT™ Oxidation catalyst system but not provided by EmeraChem is also discussed.

2. PROCESS DESCRIPTION
The combustion of hydrocarbon fuels produces various byproducts, one of which is carbon monoxide (CO). The ADCAT™ Oxidation Catalyst system converts CO to CO₂ through the use of a precious metal oxidation catalyst. A catalyst is a substance that aids in a chemical reaction but emerges from the process unchanged. This precious metal oxidation catalyst reduces the activation energy (required energy input) enabling the reaction below to occur at lower temperatures and more favorable rates:

\[ 2\text{CO} + \text{O}_2 = 2\text{CO}_2 \]

\[ \text{VOC} + \text{O}_2 = \text{CO}_2 + \text{H}_2\text{O} \]

This reaction is referred to as a catalyst aided oxidation reaction. Oxygen in the exhaust is absorbed onto the surface of the catalyst. This interaction of oxygen with the catalyst surface greatly distorts and weakens the oxygen bond. In this distorted state, the oxygen is more likely to bond to an adsorbed CO molecule eventually forming CO₂. EmeraChem uses a monolithic “discrete cell” honeycomb structure (described in section 2.2) designed to minimize pressure drop and its impacts on engine efficiency. This honeycomb structure consists of many parallel cells through which the exhaust gas must pass, thereby increasing the reactive catalyst surface.
area. The high surface area catalyst increases gas contact with the catalyst surface, thereby facilitating and advancing the oxidation reaction.

3. EQUIPMENT DESCRIPTION
The ADCAT™ Oxidation catalyst system consists of one or more catalyst modules (operated in series or in parallel) sealed against the catalyst housing using a high-temperature gasket to prevent gas bypass.

3.1. Catalyst Modules
The EmeraChem ADCAT™ Oxidation catalyst coating is applied to a substrate. The substrate is a high-temperature, metal, multi-cellular monolithic structure. This substrate structure is created using a stainless-steel alloy foil. The module is created by alternating layers of flat foil and corrugated foil to form discrete cells. The layers are layered within a stainless steel frame to form a honeycomb core. A typical Oxidation catalyst module will have on average 230-260 cells per square inch (cpsi), although higher cell densities (e.g., 300 cpsi for most reciprocating engine applications) are sometimes used to increase the surface area. Figure 1 further illustrates the concept of cell density, showing 100 cpsi as an example.

![Figure 1: Visual Example of Cell Count: 100 Cells per Square Inch](image)
Figure 2 below shows a close up picture of a metal substrate, further illustrating the previously described honeycomb cell structure. Please note that EmeraChem is able to vary the cell size and cell density to achieve site-specific performance and back pressure requirements.

![Figure 2: Catalyst Module Close-up, Illustrating Honeycomb Cell Structure](image)

Next, the assembled substrate module is oxidized at a high temperature, where diffusion bonding occurs fusing the foil layers together making the uncoated substrate rigid and strong. (When requested, EmeraChem adds a brazing flux during the assembly process to further fuse the foil layers together.) For round and octagonal module configurations on reciprocating engines, anti-telescoping bars are welded onto the inlet and outlet faces of the modules to resist the pressure of back-fires.

The completed, bonded substrate is then coated with a high surface area, stabilized alumina wash coat designed to distribute and disperse the catalytic component, and high activity platinum group metals (PGM).
3.2. Gaskets
A single type of gasket is used in EmeraChem’s ADCAT™ Oxidation Catalyst system. These gaskets are made from high-temperature fiberglass material, capable of withstanding temperatures over 1,100 degrees F. The purpose of the gasket is to seal between the catalyst modules and the mounting surface of the housing. Since the gaskets are made of fiberglass, proper breathing apparatus and gloves must be used during installation. Please see Appendix D, MSDS for more information.

4. CATALYST OPERATION AND PERFORMANCE
While in operation, the catalytic converter provides conversion of CO and VOC exhaust emissions on lean burn engines.

Bypass must be eliminated to achieve emission compliance. A seal must be properly specified and installed to prevent bypass between the catalyst module and the housing.

As a minimum requirement, the following parameters are chosen as performance indicators because they directly affect the performance of a Oxidation catalyst: exhaust gas temperature, pressure drop across the catalyst, and catalyst masking and poisoning agents.

4.1. Temperature
The catalytic activity of an oxidation catalyst is dependent on its operating temperature. Too low and the catalytic activity is low – too high and the catalyst can be damaged. The exhaust gas from a four-stroke lean-burn stationary reciprocating engine, measured at the oxidation catalyst inlet, should be between
600°F and 1150°F for optimal catalyst performance and to minimize possible degradation due to poisons and masking agents or high temperature sintering.

Catalytic conversion produces an exothermic reaction (releases heat and increases temperature) as a result of oxidizing carbon monoxide and hydrocarbons. The magnitude of temperature rise is dependent on the amount of carbon monoxide (CO) and hydrocarbons (HC) oxidized. Under normal engine operation, the catalyst exothermic temperature rise is 10 - 25°F for oxidation catalysts.

Excessive temperature can cause sintering, which is discussed below. Sintering can occur quickly if the catalyst is operated at a temperature that is too high, and the damage to the catalyst unit can lower or eliminate its effectiveness.

4.2. Pressure Drop Across Catalyst
A pressure drop that deviates by more than 2 inches of water from the pressure drop measured during the initial performance test indicates that the catalyst may be damaged or fouled. For fresh catalyst or reinstalled catalyst, a pressure drop reading is required immediately after the installation, and this reading should be recorded and used as the baseline for evaluating the catalyst.

4.3. Catalyst Masking and Poisoning Agents
The following contaminants are known catalyst deactivators and contribute to shortened catalyst life: heavy and base metals such as lead, mercury, arsenic, antimony, sodium, potassium, lithium, zinc, copper, tin, iron, nickel and chrome; sulfur, silicon, phosphorous and fluorine, chlorine, bromine and iodine. Hence, the contents of these contaminants in the catalyst must not singularly or collectively accumulate to such a level that exceeds 350mg/m³ or 10 mg/ft³ of catalyst as determined by ICP-OES (inductive couple plasma - optical emissions
spectroscopy) or glow discharge mass spectrophotometry. The presence levels of these contaminants void the warranty, unless otherwise expressly agreed to in writing by EmeraChem.

5. CATALYST STORAGE INSTRUCTIONS
Upon delivery, the catalyst should be stored in a clean, dry place with protection from rain, snow, dust, welding fumes, and any physical threats that could damage or deform the substrate cell structure. Dropping, crushing or deforming the substrate cell structure could effect performance. Due to the value of the precious metals on the catalyst elements, consideration should be taken for security. Failure to adequately follow these procedures may void the catalyst warranty.

6. INSTALLATION

6.1. Pre-Installation Instructions for Catalyst Element
- New or rebuilt engines must be operated at normal operating load and temperature for a minimum of 72 hours prior to installing the catalyst element into the housing. This break-in cycle allows time for proper seating of piston rings and valves, and minimizes the catalyst’s exposure to contaminants including potential oil aerosols and excessive masking agents.

CAUTION: Failure to observe break-in requirement will void the catalyst warranty.
- Perform emission test to confirm proper pre-catalyst emissions.
- Confirm proper exhaust temperature for catalyst operation;

6.2. Installation Instructions for Catalyst Element
Note: Installation instructions will vary with the design of the housing, the type of gasket specified by the housing manufacturer, and the housing’s catalyst hold-
down system. Please refer to the housing manufacturer’s manual for detailed catalyst installation instructions.

- Install the supplied ½” threaded lifting eye bolt in the recessed nut on the catalyst band. The purpose of this eye bolt is to assist with catalyst handling.
- Remove the housing access lid. Install a new high temperature gasket to seal the catalyst module to the housing. Depending upon the housing design, the gasket may be a tadpole gasket or a flat gasket, and it may be installed on the housing or on the catalyst module itself.
- Lower the catalyst module into position being careful to seat the module and the gasket evenly. Secure the catalyst module in place with the retaining hardware that comes with the housing.
- Remove the threaded lifting eye bolt from the catalyst module.
- Inspect the access lid gasket and determine whether it is reusable. Position the access lid gasket. If installing a new gasket, form bolt holes in the gasket using an 1/8” punch.
- Position the access lid; install the provided bolts, lock washers, and nuts; torque as directed by the housing manufacturer.
- Inspect all test ports in the exhaust system to ensure they are plugged.
- Verify that an over-temperature protection device is installed and operational. It is recommended that devices be installed upstream and downstream of the catalyst. A high-temperature limit shutdown controller is required for the downstream device and should be positioned 6 to 12 inches downstream of the catalyst. The trip point should be set to 1250°F.

**NOTE - Upon completing the catalyst installation, operate the engine at normal load/speed for a minimum of 1 hour and re-torque access lid fasteners.**
7. SAFETY CONSIDERATIONS
Always use caution when working around the system during a shutdown period. Any time the system is not in operation because of the need to perform maintenance work, use the appropriate equipment lockout measures.

The ADCAT™ Oxidation catalyst system operates in the engine exhaust stream at high temperatures. High temperatures pose a hazard to workers and make it mandatory that personnel be protected against injury. Do not attempt to work around the catalyst system if temperatures exceed 110°F. If the system has shut down because of a high temperature or any other reason, pay particular attention to hot surfaces and make sure there is adequate area ventilation. This is especially important when inspecting, removing, or installing catalyst. If necessary, use a ventilation fan to keep fresh air flowing through the system during inspection, removal, or installation. All appropriate OSHA confined space safety procedures, as well as all local and company procedures should be followed at all times.

• Follow all appropriate OSHA and plant safety procedures at all times, including equipment lockout / tag out, proper personal protection and confined space entry procedures.
• Provide adequate ventilation.
• Wear leather gloves when handling catalyst modules. Metal edges of the modules could be sharp and can cut and bruise.
• Wear safety glasses with side shields or goggles when installing or removing modules from the frame. Protruding threading studs on the housings could be at eye level.
• Wear safety shoes and a hard hat when appropriate for the site and the nature of the work being done.
• When handling heavy catalyst modules or working around catalyst housings that present awkward handling positions, use a lifting fixture and the element eyebolt to assist with loading/unloading.
• Precautions should be taken to prevent injury from falling objects from work occurring overhead.
• Review the operation of the ADCAT™ Oxidation catalyst system with the plant safety officer before starting the unit. Any suggestions and additions should be added to those instructions.

All those involved in the operation of the ADCAT™ Oxidation Catalyst system should read and understand the complete operating instructions before starting the system. Safety meetings of all those involved with the system should be held periodically in conjunction with housekeeping reviews.

8. OPERATION LOG
To maintain compliance with warranty provisions, process operating logs must be maintained. These operating logs are to contain record of the operating conditions of the system such as:
• date of catalyst installation,
• cumulative operating hours on the catalyst,
• engine load versus time,
• catalyst inlet temperature over time,
• oil type and consumption rate,
• fuel analysis (including sulfur and metals like arsenic),
• history of backfires and misfires,
• emission test results, etc.
The conditions are to be recorded on a regular basis. These process operating logs shall be available to EmeraChem at all times during the warranty period.

9. CATALYST DEACTIVATION & MAINTENANCE
There are conditions that will deactivate or destroy the catalyst. Understanding how a catalyst deactivates, and avoiding those conditions, will ensure maximum performance and service life from the catalyst.

9.1. Catalyst Inspections
The catalyst should be physically inspected at 6 to 12 month intervals for gas-fired systems with low loading of exhaust gas particulate and low oil consumption rate. Based upon experience, monthly inspections may be necessary for systems with high oil consumption, fuel containing high sulfur or other catalyst contaminants, and/or prone to misfires and over-temperature events.

Carbon fouling is evident by a soft, sooty black deposit on the catalyst. These carbon deposits will eventually restrict flow and increase back pressure. They will also mask the active surface area of the catalyst resulting in degraded emission performance and reduced exothermic temperature rise. These carbonaceous deposits could ignite on the catalyst surface during an engine misfire. Carbon fouling could originate from an improper air-fuel ratio.

Ash fouling is evident by a grayish-white powdery deposit on the catalyst that could accumulate to the point of plugging substrate cells. These ash deposits will eventually restrict flow, increase back pressure, mask the active catalyst surface area, and reduce emission performance. Ash fouling originates from an engine oil with high sulfated ash content, and can be exacerbated by an overly lean air-fuel ratio.
Oil fouling is evident by dark brownish-black coating on the catalyst and possibly the odor of crankcase oil. These oil deposits will eventually mask the active catalyst surface area and degrade performance, restrict air flow and increase back pressure, and cause high temperature alarms and shutdowns. Oil fouling originates from too much lube oil entering the engine exhaust gas.

Over-temperature often occurs within the core of the catalyst and may not be evident until damage is severe. Possible indications may range from a clean white, powdery appearance, to small pin-holes in the foil near the leading edge, to catastrophic incineration of the catalyst module. Over-temperature conditions originate in the engine from misfires, sticking exhaust valves, out of spec air-fuel ratio, and other engine causes.

9.2. Catalyst Masking
The catalyst elements in reciprocating engine applications operate in an environment with known contaminants and potential elevated temperatures that will gradually decrease the destruction and removal efficiencies (DRE). Under normal operating conditions, the DRE will gradually decrease as a result of masking – a process by which contaminants deposit and accumulate on the catalyst surface. Eventually, the accumulation covers the active surface area of the catalyst and prevents the exhaust gas from contacting the active precious metal sites. Even though the deposit may be too thin to effect pressure drop, the performance will decline. Sulfated ash masking is the most common form of masking and is a product of the combustion of lubrication oil. Masking is often a reversible process in which the DRE can be restored with a chemical wash process. EmeraChem offers chemical analysis and chemical washing services upon request.
CAUTION: Unapproved washing processes or chemicals can cause irreversible damage to the catalyst, and will void the warranty. To minimize the frequency of chemical catalyst washes, the engine should be operated with low ash (<0.5% wt) crankcase lubrication oil. Periodic emission testing is required to monitor, and record the catalysts DRE to determine the catalyst wash frequency. Typical catalyst wash frequency occurs within 12 — 24 months of continuous operation, and can vary depending on many factors including, but not limited to, oil type and consumption rate, exhaust temperature, engine load, catalyst sizing and required DRE.

9.3. Catalyst Fouling
Fouling occurs when solids physically plug the cells of the substrate and block gas flow through the catalyst. This can be caused by large particulate material in the gas stream or by deposition of an inorganic component (e.g. silica) and organic components (e.g. ash, carbon) as a by-product of combustion. Although the catalyst reduction performance may not be affected, disruption of exhaust flow through the catalyst causing high engine backpressures will degrade engine performance and may result in engine stalls and high fuel consumption. When possible, the source of the fouling agent should be identified and corrected. A fouled catalyst can usually be restored by vacuuming or by chemical washing. CAUTION: Do not use high pressure compressed air to blow off the catalyst module. Erosion of the catalyst coating may result.

9.4. Catalyst Poisoning
Certain materials can react with the active catalyst surface to form compounds or alloys that are not catalytically active. For example, lead and phosphorous can form alloys with platinum, forming a catalytically inactive metal, and reducing the performance of the catalyst. This process is usually irreversible – little can be
done to rejuvenate a poisoned catalyst and replacement is usually necessary. Before replacing the catalyst identify the poison contaminant(s) and eliminate the sources.

Known catalyst poisoning agents, that can cause irreversible loss of catalyst activity, include lead, mercury, arsenic, antimony, sodium, potassium, lithium, zinc, copper, tin, iron, nickel, chrome, silicon, phosphorous and fluorine. Content of these contaminants, in the catalyst, must not singularly or collectively accumulate to a level that exceeds 350mg/m³ or 10 mg/ft³ of catalyst. Common sources of poisoning agents include, fuel (landfill gas, digester gas, refinery gas, arsenic-laden natural gas), lubrication oil, coolant, anti-seize, RTV silicon and airborne contaminants. EmeraChem offers analytical chemical services to identify and quantify the presence of catalyst poison compounds.

9.5. Catalyst Thermal Deactivation
Under normal engine operation, the catalyst exothermic temperature rise is 50 - 75°F for three-way catalysts; and 10 - 25°F for oxidation catalysts. Maximum post-catalyst temperature is 1250° F. In the event of a misfire, excessive concentrations of hydrocarbons and air generated from the cylinder(s) can lead to irreversible catalyst damage, if not quickly corrected. Misfire(s) forces the catalyst into an uncontrolled combustion mode, in which the catalyst combusts all the hydrocarbons the exhaust oxygen will support. The net result is an exothermic reaction elevating the catalyst temperature above the normal operating range, and sintering of the catalyst. Once sintering has occurred, catalyst pore volume and internal surface area a permanently lost and precious metal sites are permanently lost.
Note that even if the engine exhaust temperature is within the catalyst operating specification, if excessive unburned fuel reaches the catalyst, a large exotherm could occur within the catalyst itself, raise the catalyst core temperature, and sinter the catalyst element.

*Note:* A single, continuous misfire on a V-12 natural gas engine can increase the catalyst temperature by 350°F which, if left uncorrected, could cause irreversible damage to the catalyst’s alumina washcoat, and result in permanent performance deterioration. In severe cases, misfire(s) can cause exhaust temperatures to exceed 2500°F, and result in catastrophic failure of the catalyst substrate.

### 9.6. Catalyst Cleaning

Loss of performance or an increase in pressure drop or temperature rise across the unit may indicate the need to clean the catalyst. The frequency and best procedure for cleaning will depend upon the nature and concentration of fouling or masking agents in the exhaust gas stream. Testing (available from EmeraChem) may be required to find the best procedure and frequency for a particular installation. Under normal operating and maintenance conditions an element may require cleaning every 12 to 24 months.

The most effective and least damaging method of cleaning catalyst is with chemical washing. Chemical washing has been shown to remove ash and chemical contaminants deposited by fouling and masking mechanisms. EmeraChem offers a proprietary 4-step recirculation process using alkaline and acidic solutions.
Vacuuming in the direction opposite the normal flow through the catalyst can often remedy fouling, especially by particulate trapped from the gas stream. Vacuuming may be possible with the catalyst in place if there is sufficient access room.

Blowing the catalyst clean is not recommended because of the potential to erode the catalyst coating off the substrate with the use of high pressure air, or contaminate the catalyst with oil from an air compressor.

10. TROUBLESHOOTING
The operator must understand the important relationship between the engine, the air/fuel ratio, and catalytic reactor to diagnose emission related problems. The ability of the catalyst to perform at the permitted compliance level is directly dependant on the composition and temperature of the engine exhaust. Although an engine need not be in new condition, it must (at a minimum) meet design specifications as detailed by the engine OEM.

10.1. Engine Related Issues

10.1.1. Ignition System Misfire
An ignition misfire will cause cylinders to release unburned hydrocarbons and air into the exhaust system. A misfire is generally indicated by an abnormal level of CO spikes and hydrocarbons greater than 2000 ppm.

10.1.2. Leaking Exhaust Valve
Leaking exhaust valves will allow combustion products to prematurely escape the cylinder. General indications of a leaking exhaust valve include elevated levels of CO in the engine’s exhaust.
10.1.3. Low Compression
Low cylinder compression will cause combustion instability resulting in higher CO levels.

10.1.4. Low Load
Reduced engine load (< 50%) produces characteristics very similar to low compression, because the volumetric efficiency is reduced. Low load is indicated by high vacuum in the intake manifold for naturally aspirated engines, or no power boost on turbocharged engines. Catalyst efficiency is reduced due to unstable combustion and low exhaust temperatures.

10.1.5. Detonation
Detonation can be attributed to improper ignition timing, an over loaded engine condition, improper air-fuel ratio, or high BTU fuel gas.

10.1.6. Improper crankcase routing
If crankcase ventilation is designed to be routed to the exhaust, vent must be routed downstream of the catalyst.

11. REVISIONS AND CHANGES
EmeraChem reserves the right to amend the Operation and Maintenance Manual as necessary. Such amendments to the Operation and Maintenance Manual shall not be applied retroactively in determining the customer’s warranty compliance.