Catalytic Oxidizer Design and Operation Basics

Our engineers and service team have compiled this e-book to help operators of catalytic oxidizers understand the design basics of any catalytic oxidizer along with a series of maintenance tips. We hope this ebook provides the reader with useful information to help keep your catalyst or catalytic oxidizer operating at optimum performance. This ebook will focus on the following topics:

- Catalyst Basics
- General Operating Guidelines
- Catalyst Inhibitors
- Analytical Services
- Removal and Installation Guidelines

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Catalytic Oxidizer

Catalyst Basics

There are hundreds of types of catalyst products at work in the world today. This ebook will focus only on the use of precious metal catalyst used in VOC air pollution control systems. The most traditional air pollution control device that employs a precious metal catalyst is a Catalytic Oxidizer. Although catalyst has been used in Regenerative Thermal Oxidizers as a means to lower the operating temperature and reduce natural gas consumption. Additionally, a catalyst can be installed in a catalytic reactor or catalyst bed where the pollutants are found in a pre-heated exhaust stream. This series will be applicable to all catalytic oxidizers (incinerators) used for VOC abatement.

There are three primary types of catalyst products at use in modern catalytic oxidizers.

Metal Monoliths or sometimes called Honeycomb. These products will be installed in a stainless steel module and mounted in a fixed bed or grid

Ceramic Monoliths or sometimes called Honeycomb. These products will be installed in a stainless steel module and mounted in a fixed bed or grid.

Ceramic beads or spheres. Allows pour ability and usually contained in a catalyst tray.

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Catalyst Operating Guidelines

Catalyst performance depends on the original design criteria from the catalytic oxidizer manufacturer. Performance is dependent on catalyst volume, pressure, temperature, and VOC type and concentrations.

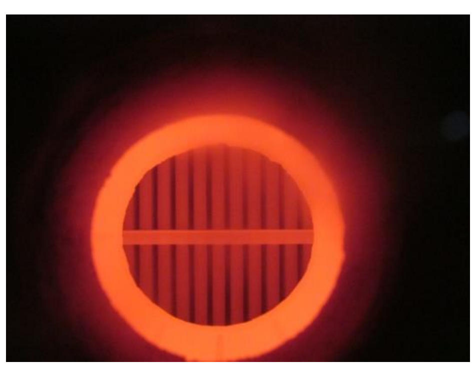
The performance of the catalyst is related to care in installation to ensure no by-pass or leakage of exhaust gases through the catalyst bed. It is also a function of even, uniform flow and temperature across the face of the catalyst bed. The performance of the catalyst will also depend on how well the catalyst is maintained during its operational life.

The following briefly describes the effect of each factor on the catalyst and how the operator should respond.

TEMPERATURE:

The operating temperature range has been chosen in order to achieve the correct destruction efficiency. The catalyst functions within a specific temperature range. Below the minimum operating temperature, the catalyst will not operate and there will be no destruction of the VOC's. Above the maximum temperature, the catalyst is subject to thermal degradation. The result is a shortened catalyst life.

In order for oxidation of a compound to occur, sufficient energy must be present to break up the molecule. This is done in thermal incineration by simply subjecting the compounds to very high temperatures for a fixed amount of time. Catalysts make it possible to carry out the same destruction of a given compound at substantially lower temperatures. However, there is a minimum temperature required for the destruction to occur. Some compounds are more difficult to destroy, e.g. Methane, than others, e.g. Toluene.



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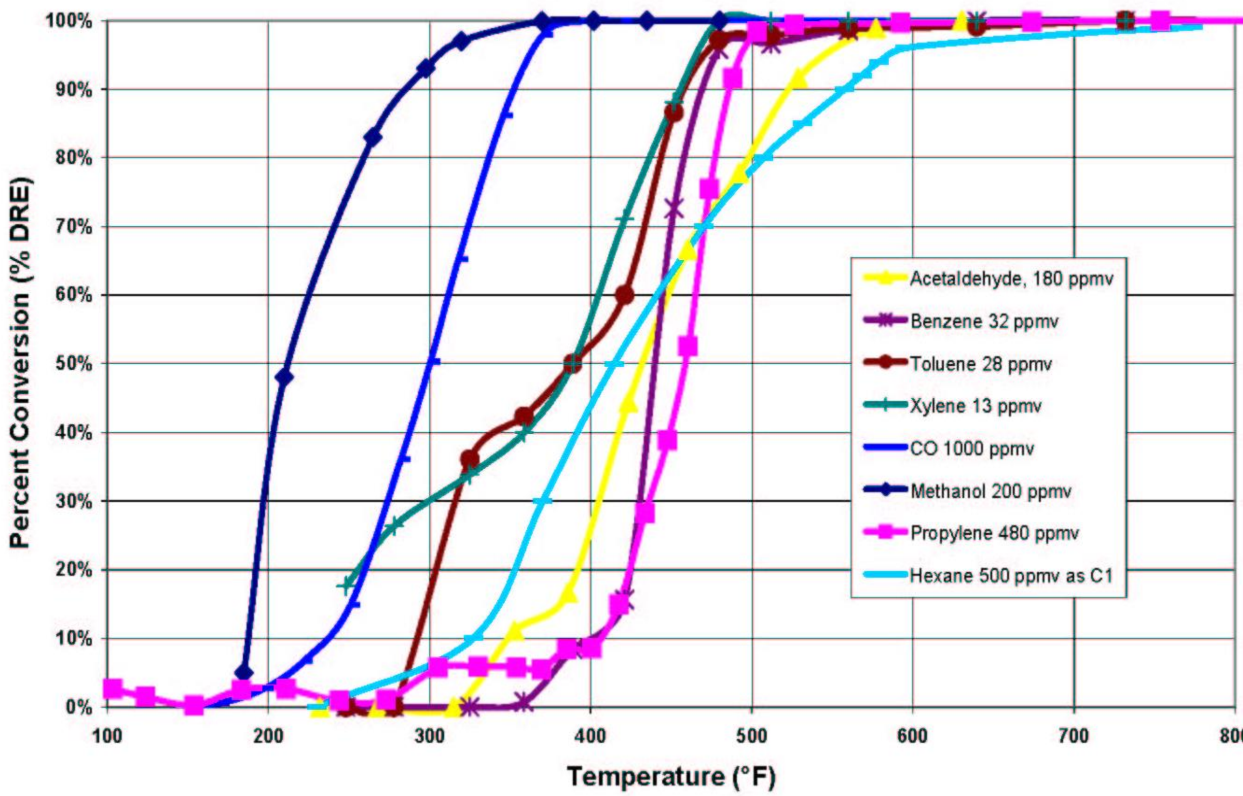

The graph above provides some indication of the relationship that temperature plays on removal efficiency and also points out how different VOC's have varying reactivity. For instance, Methanol can achieve 95% removal efficiency at a temperature near 300 F while Hexane requires almost 600 F for the same 95% removal efficiency.

While VOC's are being processed through the system, a recording device should track recording the temperature entering and exiting the catalyst. This serves several purposes. It provides historical information regarding the catalyst inlet and exit temperatures. This is extremely important for knowing what the maximum temperatures the catalyst has been subjected to. It can point to upset conditions that may have occurred and indicate their severity. It can also indicate the relative condition of the catalyst.

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In some applications, the VOC loading can be very high, creating a large exotherm of temperature across the bed of catalyst. Under any circumstances, the catalyst outlet temperature should not operate above 1250°F. If it is necessary, the inlet temperature can be lowered by 25°F increments in order to achieve the desired outlet temperature.

With lower VOC loading conditions, it may sometimes be necessary to increase the catalyst inlet temperature in order to achieve the proper outlet temperatures.

In some instances, temperature rise across the catalyst bed can indicate the relative condition of the catalyst. With a consistent, continuous process which yields a consistent temperature rise, any decrease in the amount of rise will suggest that the catalyst has undergone some deactivation. Catalyst activity testing and/or characterization can be performed to confirm the condition of the catalyst.

TIP:

As a rule of thumb, there is a 25° F rise in temperature across the catalyst for each percent (1%) of L.E.L. (Lower Explosive Limit) of solvent. Consult the original equipment manufacturer for specific information concerning this topic

BACK PRESSURE:

The presence of the catalyst in the exhaust stream will introduce back pressure or a pressure drop. The result is that more effort is needed to push the exhaust through the system than without the catalyst present. The back pressure induced is a function of the volume of exhaust gas, its temperature, the surface area cross section of the catalyst bed, and the depth of the catalyst. For example, a given exhaust flow at 600°F will have less pressure drop than the same exhaust flow at 800°F. Likewise, a given exhaust flow will have greater pressure drop across a catalyst bed of 12" than for 6".

In practice, the pressure drop across the catalyst should be constantly monitored in order to detect any sudden changes. It is a good measure to indicate the relative accumulation of particulate matter on the catalyst surface. A significant change of 20% or more would generally indicate that the catalyst may require servicing.

During the design of the catalyst for your application, the amount of back pressure induced by the catalyst was considered with respect to the capacity of the fan in the system. More powerful fan motors are required to push through high back pressures. The effect is more energy consumed during the operation of the catalytic oxidizer.

SPACE VELOCITY:

Your catalyst has been designed for a certain specific space velocity in order to meet the required destruction efficiency of your application. This means that a given number of cubic feet of catalyst was determined for the application, based on the exhaust flow rate, the type of solvents exhausted, their concentration, and destruction requirement.

Space velocity is determined by dividing the flow rate under standard conditions by the catalyst volume in cubic feet. The units are reciprocal time (hr-1). It is the same as the inverse of the residence time (1/residence time). The typical space velocity range for VOC catalyst products is between 20,000 - 50,000 hr-1.

Space Velocity is calculated by the following:

$$\frac{\text{Standard Air Volume (scfm) the catalyst is subjected to} \times \text{ 60 min/hr}}{\text{Volume of catalyst used (ft3)}}$$

For example:

5,000 scfm of process exhaust treated over the catalyst bed
The catalyst bed has 20 cubic feet of catalyst

$$\frac{5{,}000 \times 60}{20} = \mathbf{15{,}000\ hr^{-1}}$$

FACE VELOCITY:

Face velocity refers to the speed of the gas traveling through the catalyst bed. The feet per minute (fpm) of air movement, as it is commonly referred to, is the speed of the gas. The measurement can be taken either hot or cold. The typical linear face velocity for VOC catalyst is between 400 - 650 fpm at standard conditions, i.e. 70°F.

VOC DATA LOGBOOK:

A record book should be kept corresponding to each individual coating that is run with the catalytic oxidizer. This can be a valuable source of information in keeping track of the performance of the catalyst. Running the same production on a periodic basis and recording the temperature rise should yield similar results. If the temperature rise is diminishing over time, this is an indication that the catalyst performance is falling off. For example, Product Y is run at a certain line speed and produces a 10% L.E.L. using specific organic solvents. From previous experience, we've noted a 250°F rise in temperature across the catalyst. If this temperature rise falls over time, then the catalyst may need to be serviced.

LIFE CYCLE CURVE

Catalyst activity does not typically drop off dramatically under normal circumstances. With annual catalyst testing, the life of a catalyst can be predicted with good accuracy. In some instances, the user will find a noticeable decrease in temperature rise, which can be directly proportional to a drop in the destruction efficiency. From experience, this can be between 30,000 - 50,000 operating hours depending on a variety of factors. The catalyst life is dependent on the type of VOC's, amount and type of inorganic masking agents present, number of times cleaned, and operating temperature.

Typical catalyst masking agents are silicone, phosphorous and base metals such as iron, lead nickel, chrome, tin and titanium.

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Catalytic Products International offers complete catalyst cleaning, testing and characterization services for troubleshooting your catalyst.

MAINTENANCE PROCEDURES:

Field maintenance of VOC catalyst is limited to high temperature de-carbonization and dust removal. If the operator determines that the temperature rise has diminished from when the catalyst was fresh, it is recommended that he contact CPI Service Department to schedule a catalyst activity test. It is possible for the operator to perform a couple of operations to try to reclaim some of the catalyst performance.

Occasionally, condensable organic matter and carbon will accumulate on the surface of the catalyst. These materials can mask or block catalytic activity. It is possible to carefully remove these materials, thermally, via a burn out. A "burn-out" should be performed while the process is not running and sending VOC laden air to the oxidizer. Fresh air should be allowed to flow into the oxidizer at maximum flow. The oxidizer temperature can slowly be increased to approximately 950 - 1000°F entering the catalyst. At this temperature, with no VOC's present, the catalyst will burn off accumulated unburned VOC's and organic particulate matter. Extreme care must be taken not to exceed these temperature limitations. An adequate period of time should be between 2 - 3 hours. On occasion, some smoking could occur as a result of rapid burning of accumulated carbon.

If the pressure drop across the catalyst has been increasing, then it will need to have the accumulated dust removed. This procedure should be performed after the high temperature burn. The catalyst should be removed manually from the oxidizer and blown out using an air lance at not more than 80 psi. Air lancing with the catalyst in situ can be done with two people. The second person should stand on the opposite side of the catalyst bed and vacuum the dust which is being blown through the catalyst cells.

Do NOT use high pressure steam since this could result in a loss of precious metals from the surface.

If either or both of these procedures do not satisfactorily return the catalyst performance, then it may need chemical rejuvenation. The effectiveness of chemical cleaning can be determined at by CPI with activity testing before and after cleaning.

Catalyst Inhibitors:

If you are unsure of the presence of any compounds, check with your coating supplier and/or your Catalytic Oxidizer Manufacture prior to proceeding. They will be able to tell you definitively what compounds are in their products.

Or feel free to consult with Catalytic Products International as we are familiar with many different processes that may contain certain catalyst inhibitors.

The following chart includes some examples of common catalyst poisons or inhibitors that can void the catalyst warranty include:

Type of Inhibitor	Effect
FAST ACTING INHIBITORS: Phosphorus, Bismuth, Lead, Arsenic, Antimony, Mercury	Irreversible reduction of catalyst activity at a rate dependent on concentration and temperature.
SLOW ACTING INHIBITORS: Iron, Tin, Silicone	Irreversible reduction of catalyst activity at a rate dependent on concentration and temperature.
REVERSIBLE INHIBITORS: Sulfur, Halogens, Zinc	Reversible surface coating of catalyst active area at a rate dependent on concentration and temperature. These may be removed by increasing the catalyst bed temperature. (contact CPI for instructions)
SURFACE MASKERS: Organic Solids	Reversible surface coating of catalyst active area. These may be removed by increasing the catalyst bed temperature. (contact CPI for instructions)
SURFACE ERODERS & MASKERS: Inert Particulate	Irreversible reduction in activity due to surface coating of catalyst active area and or erosion of surface at a rate dependent on particle size, grain loading, and gas stream velocity.

Analytical Services

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Catalytic Products International offers complete catalyst cleaning, testing, and characterization services for troubleshooting your catalyst. Below is a listing of various testing methods available.

Activity Test: Standard test that compares the activity of your sample to that of similar new catalyst. A table of results and graphic chart showing VOC destruction efficiency for standard gas samples (toluene or hexane)

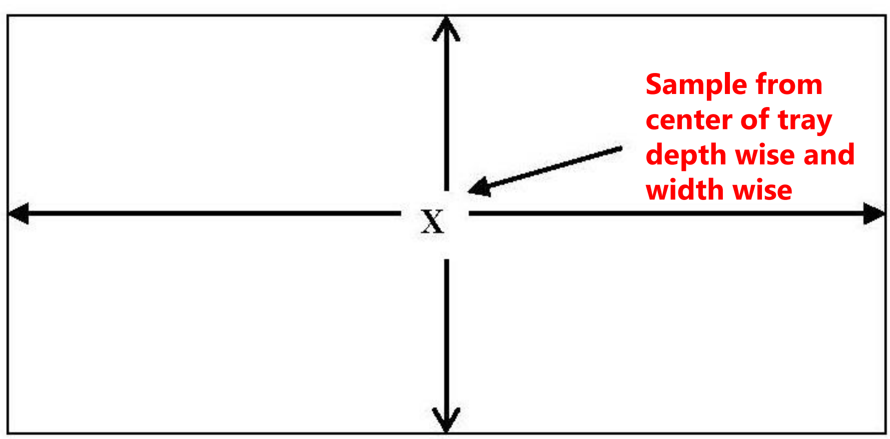
X-Ray Fluorescence: Used after the standard activity test shows less than expected results and in instances when poisoning is thought to have occurred. This will specify what contaminates may be found on the surface of the sample

BET Surface Area: Used after the standard activity test shows less than expected results and in instances when high temperatures are thought to have damaged the catalyst.

Precious Metal Analysis: Used after the standard activity test shows less than expected results and in instances when particulate attack or loss due to attrition is thought to have occurred.

CATALYST SAMPLING PROCEDURE (Beads):

1. Shut down the oxidizer and wait for the internal temperature to fall below 100°F (Reference oxidizer operating manual).
2. Open the access door to the catalyst inlet bed (door closest to visual site ports).
3. Enter the catalyst chamber following any applicable plant safety procedures for confined space entry.
4. Select a tray near the center of the oxidizer (i.e. the middle tray if there is an odd number or either of the two middle trays if there is an even number, just not the top or bottom tray).
5. Remove the clevis and cotter pins from the front cover piece.
6. Remove the front and top covers.
7. If guard bed is included (white catalyst) obtain a sample of the guard bed. Take the sample from near the center of the tray. Carefully scoop a quantity of at least 200 cubic centimeters (CC) into an appropriate sample container. Note that this layer of guard bed is typically only 2" deep with a protective mesh underneath, so you will not be able to scoop very deep.



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8. To obtain a sample of the catalyst, you will need to access it underneath the guard bed layer and protective mesh. With the covers removed from step 6, you should be able to push the guard bed beads towards the back of the tray. Lift the protective mesh at the front edge of the tray, being careful not to mix the guard bed beads with the catalyst beads. Again, scoop a quantity of at least 200 CC's of catalyst into an appropriate container from the center of the tray. Note that there is a second layer of protective mesh with another layer of catalyst underneath, so you will not be able to scoop to the bottom of the tray. You only need to sample from this layer of catalyst, not the bottom most layer.
9. Smooth the catalyst remaining in the tray where the sample was taken from.
10. Replace the protective mesh between the guard bed and catalyst.
11. Smooth the guard bed evenly across the tray.
12. Replace the covers, clevis pins, and cotter pins.
13. Exit the oxidizer and replace the access doors.
14. Put the oxidizer back into service.

Annual testing helps keep you EPA compliant

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Cleaning and Rejuvenation (Modules):

Catalyst can be serviced at our factory at very little cost. The catalyst cleaning can be performed in a minimal amount of time. An average lot of catalyst can be processed in approximately one-two weeks. The cleaning is designed to remove dust, particulate matter, organic precipitates, carbon, and inorganic materials.

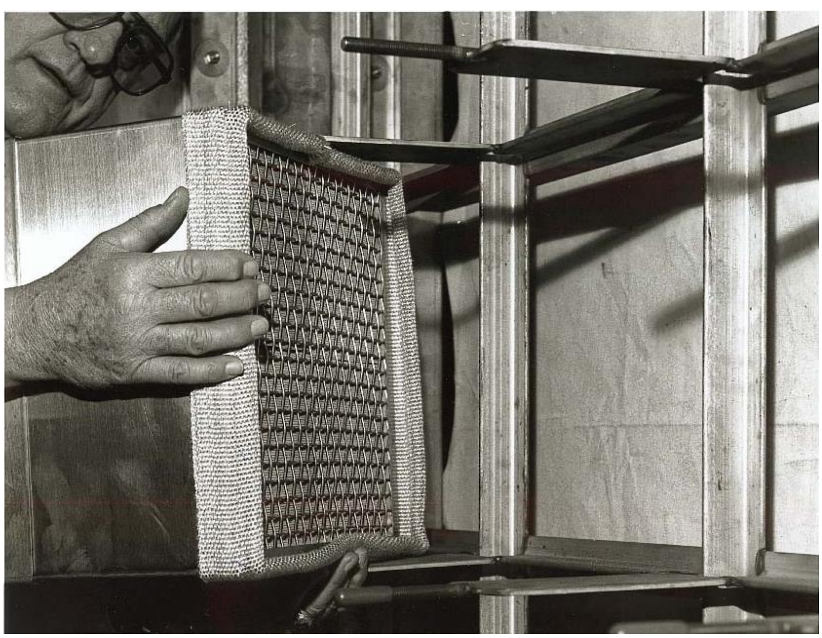
We typically recommend that this service be performed once every two years. It should be noted that our company is aware of some clients using the catalyst for ten years time that have never performed any cleaning service.

The cost for cleaning of the catalyst is only a fraction of that of a new charge and should therefore be considered as an investment designed to prolong the life of the catalyst.

REINSTALLATION PROCEDURES:

This procedure describes the proper method of installing catalyst modules in a support frame. The support frame is mounted in a stainless steel duct or chamber downstream of a burner. Usually the support frame is mounted with the module retention clips and brass or monel nuts in place on the module retention studs to be sure they do not get lost. The module retention clips and double brass or monel nuts need to be removed and set aside for use as each module is mounted in place.

The catalyst module and frame interface is sealed with a tadpole type gasket. Prior to mounting the module in the frame, the tadpole gasket must be mounted on the end of the module which will touch the frame. Make certain the area of the gasket that is overlap sewn (tail and bulb are thicker) to make the continuous loop, is roughly in the center of a can side, not on a corner. Roll the bulb over the lip of the can. Pinching the bulb at each of the four corners will help hold the bulb over the lip. There is very little space around each of the frame holes. If there is insufficient space to hold the gasket in position with one hand while maneuvering the module between the T-bar extension plates and studs, a strip of masking tape in each direction may be used. Orient the module such that the thick part of the gasket is at the top.



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With the gasket in place on the end of the module, there is very little free space between the threaded studs to slide the module straight into position. The gasket can get caught on the stud threads. To avoid this problem, maneuver the module into position at an angle, moving sideways as well as inward allowing the gasket to slip in behind the studs between the flat extension plates. Both hands should be in contact with the gasket bulb, keeping it in position in front of the module lip.

As you slide the module into position sideways, now partially supported by the extension bar, make certain by touch that the bottom bulb does not get caught on the edge of the T-bar frame. The gasket will roll out of position otherwise. Keep sliding the module sideways and forward so one side engages the frame first. Make certain the gasket bulb is on the module lip between it and the frame, and not rolled back to the side of the module. With the module seated sideways as far as it will go, push the other side of the module into the frame, making sure the gasket bulb is out in front of the lip.

By visual observation or by touch, check to see that the top and bottom bulbs are in place in front of the module lip. Once in place within the T-bar opening, there is not room for the gasket to roll back. Once the module is past the studs and between the T-bar extensions, avoid pulling the module away from the frame because the gasket may slip off the module end which will require starting the procedure over again.

Once the gasket bulb is seated on all sides of the module push the module firmly against the frame and install those module retention clips that will not interfere with the next module placement. It is possible to check the gasket position by finger touch with an arm extended through an adjacent frame opening. Removal of masking tape that may have been used to hold the gasket in place may be accomplished in the same manner..

Do NOT remove the combustible tape holding the lid in place. Like masking tape, it will burn off during start-up.

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Always start the module installation in a top corner frame opening, and then proceed across or down. The purpose is to allow room for full hand and arm support of the module from the bottom and with the other hand on a side. Of course, this whole procedure is much easier if the module installer has another person on the back side of the frame guiding the module and gasket into proper position on the frame.

When all of the modules are in place with all the module retention clips and one of the brass or monel nuts hand tightened, the nuts can be tightened a little at a time. Make at least three passes to bring all the nuts up to 50-75 inch pounds of torque. If an inch pounds torque wrench is not available, tighten only to the point where firm pressure depresses the gaskets half way. Try to observe the length of stud showing above the tightened nut as a means of determining that the modules are compressing the gaskets uniformly. After the nuts have been tightened uniformly as possible, use the second nut as a jam nut with a firm torque while holding the position of the first nut.

Removal of the modules is accomplished in the reverse order of the described above, i.e. starting at the bottom row and proceeding across or up. When modules are removed for annual or biannual cleaning, new gaskets should be used for reinstallation.

Have more questions?
Contact our EXPERTS at

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