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# CAT Series
# Ozone Destruct Units

## User Manual



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## GENERAL NOTES

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- Teledyne API (TAPI) reserves the right to make changes to the product covered in this manual to improve performance, reliability or manufacturability. Make sure that this Manual is used with the original Product it was shipped with.
- Although every effort has been made to ensure accuracy of the information contained in this manual, TAPI assumes no responsibility for inadvertent errors. Contents of the manual are subject to change without notice.
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# 1 Introduction/Safety

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## 1.1 General safety guidelines

**DANGER**

**TOXIC GAS**

Ozone ($O_3$) is a toxic gas. High concentrations of ozone are dangerous and harmful to humans. Take reasonable steps to avoid exposure. The current maximum 8-hour exposure limit for ozone is 0.1 PPM (according to U.S. OSHA).

Install appropriate safety monitoring equipment wherever high concentrations of ozone are used. Use of safety monitor equipment in all applications is highly recommended. TAPI manufactures several ozone monitors for workplace safety applications.

Materials in contact with high concentrations of ozone should be suitable for such use. Stainless Steel (316L), Teflon®, and Chemraz® are recommended.

Never attempt to open ozone catalyst canisters (if supplied). The contents of the canisters can be hazardous if not handled properly.

**WARNING**

**BURN HAZARD**

Certain components may be hot to the touch. Please allow proper cooling time before working with these components.

**CAUTION**

Read the operating manual before operating the unit.

Do not subject the unit to extreme physical or thermal shock.

Use care in handling the unit and any of its components.

DO NOT use this equipment in any manner not specified by the manufacturer. If the equipment is used in a manner other than as specified in this document, the safety protections may be impaired.

Use only TAPI recommended spare parts. Substitution parts could result in damage to the equipment and/or may create hazardous conditions and will void the warranty.

## 1.2 Gas Hazards

### Ozone Safety

Ozone has the potential to injure humans and damage the equipment and facilities by corrosion or explosion. TAPI's ozone delivery system uses high voltages that can cause injury or death by electrical shock. One should also be aware of chemical and physical risks.

**DANGER**

**Understand and implement the OSHA and locally required safety laws involving the generation of ozone gas using high-voltages. Failure to do so may lead to personnel injury. TAPI assumes no liability for the user's failure to comply with these requirements. Ensure that every action is done under attention of all safety regulations!**

**DANGER**

**Ozone has a readily identifiable odor recognizable in extremely minute quantities. Concentrations above 0.1 ppm can cause headaches, eye irritation, respiratory problems, dizziness, and nausea. At much higher concentrations it can cause death.**

**TAPI has available low concentration ozone analyzer, Model IN-2000 which can be used to monitor for the presence of Ozone leaks. The Model IN-2000 is typically connected to the Ozone Delivery System (ODS) to stop all ozone generation and close the outlet valve if an ozone leak is detected. Consult TAPI for recommendations for your installation location.**

**An alternative methodology to locate small leaks (during installation) on tubing and fittings that contain Ozone, is the use of potassium iodine/starch paper. It is a commercially available indicator paper for Ozone. After wetting the paper with water, it shows a color change in contact with Ozone.**

**DANGER**

**Do not use an ozone generating system without an Ozone leak monitor. Failure to do so may lead to personal injury.**

**Observe the safety thresholds for Ozone concentration that apply in your country. (In the USA, the maximum permissible workplace concentration is 0.1 ppm = 0.2 mg/m3). Failure to do so may lead to personal injury.**

**DANGER**

**Please observe the necessary safety measure when working with high Ozone concentrations.**
**In the U.S.A., the ACGIH TLVs are defined as:**
**0.1mg/m$^3$ for heavy work,**
**0.16mg/m$^3$ for moderate work,**
**0.2mg/m$^3$ for light work**

**The OSHA PELs are: 8-hr TWA= 0.2mg/m$^3$ (0.1 ppmV), STEL: 0.6mg/m$^3$ (0.3 ppmV).**
**NIOSH REL lists a ceiling of 0.2mg/m$^3$ (0.1 ppmV)**

**DANGER**

**EXOTHERMAL and PRESSURE HAZARDS**

Gaseous ozone may decay exothermally. At higher concentration the exothermal and volume increasing decay of ozone might result in increased pressures. The decay can by catalytically induced. Therefore, never use materials that catalyze the decay of ozone within the gas lines.

Materials in contact with high concentrations of ozone should be suitable for such use. Stainless Steel (316L), Teflon®, and Chemraz® are recommended.

**DO NOT use silver plated gaskets for VCR fittings** since they catalyze the decay of ozone severely.
**Use non-plated stainless steel gaskets only!**

**DANGER**

**LEAK-THROUGH HAZARD!**

**The units should also ALWAYS be mounted vertically with the gas inlet at the bottom. Labels are provided to indicate to the user the inlet side of the unit.**

## Fire/Explosion Hazard

**DANGER**

**FIRE/EXPLOSION HAZARD**

**Non-flammable materials may become flammable in the presence of high oxygen and/or ozone concentrations!**

## Material Safety Data Sheets

Material Safety Data Sheets (MSDS) for each hazardous chemical should be consulted in case of exposure. The MSDS covering all hazardous materials used in the process must be prominently displayed in the immediate vicinity of the machine.

# 2 System Overview

## 2.1 System Overview

The CAT Series of ozone destructors decompose ozone to safe levels through the catalytic conversion of ozone ($O_3$) to oxygen ($O_2$).

Ozone decomposes as a result of chemical adsorption at the solid surface of a metal oxide catalyst. The ozone molecules are held to the catalyst surface by forces comparable in strength to their own chemical bonds. Those bonds are weakened, and ozone decomposes in an exothermic reaction to form oxygen.

The Teledyne API, IN USA-brand destructors are customized to handle ozone destruction requirements with improved performance, maximum lifetime, and reduced costs. Applications include:

- CVD TEOS/Ozone
- ALD
- MOCVD
- Ashers
- Wet Benches
- Spray Tools
- Other


*Figure 1. CAT Series Ozone Destruct Units*

Ozone ($O_3$) is a highly reactive chemical compound comprised of three atoms of oxygen. Because of its reactivity and exceptional oxidative power, it is used in a wide variety of industrial applications that include municipal water and wastewater treatments, chemical processes, and semiconductor wafer manufacturing. The ozone generated for these applications can reach concentrations of 20 % by weight (120,000 ppmv) or more, leading to the need for effective post-reaction ozone destruction systems, in order to protect personnel, equipment, and the environment.

Ozone destruction systems should ideally lower $O_3$ concentrations to environmentally safe levels, below 0.1 ppmv (0.2 mg/$m^3$) for an 8-hr day, over a wide range of sampling conditions. The temperature, flow, and humidity levels of an ozone-containing sample can dramatically affect the destruction efficiency of any system if it is not properly designed. To meet the majority of ozone destruction requirements, ***TAPI*** offers destructs systems based upon the catalytic decomposition of $O_3$ to oxygen.

System Features include:

- Rapid reaction time
- Room temperature ozone destruction
- Greater than 99+% $O_3$ removal
- No reactor consumption
- Environmentally safe decomposition product ($O_2$)
- All welded construction
- Self-contained
- No Consumables
- No Maintenance
- Simple installation
- Very compact

## 2.2 Principle of Operation

The decomposition of ozone to oxygen is an exothermic (spontaneous) reaction that liberates 34 kcalories of heat for every mole of $O_3$:

$O_3 \Rightarrow 3/2\ O_2 \qquad \Delta H = -34$ kcal

An ideal catalyst is not consumed in the reaction but participates in such a way as to increase the reaction rate. The effectiveness of the catalyst is due to its ability to lower the reaction activation energy, where the activation energy represents the energy required to bring the reactants ($O_3$ molecules) to the point where they can rearrange to form products ($O_2$ molecules). A heterogeneous catalyst is used to achieve this, where the catalyzed gas phase decomposition takes place on a solid surface.

Decomposition catalysis comes about as the result of chemical adsorption of $O_3$ molecules at that solid surface. The $O_3$ molecules are held to the surface by forces comparable in strength to its own chemical bonds. Those bonds are thereby weakened, and the $O_3$ becomes more susceptible to decomposition.

The effect of certain "poisons" in inhibiting the catalysis reaction can be readily explained in terms of the adsorption mechanism. A foreign substance, which is more strongly adsorbed on the surface of the catalyst, reduces the fraction of surface area available for adsorption of the $O_3$ molecules. In extreme cases, traces of inhibitors can completely cover the surface, reducing the rate of the catalyzed decomposition to zero.

A manganese dioxide ($MnO_2$) based catalyst that has been proven in extensive testing is used to meet the majority of $O_3$ destruction requirements.  To meet those requirements, taken into account are the inlet ozone concentration, the sample residence time, linear velocity, temperature, and relative humidity level.  These critical operating parameters are combined in an empirically developed model that predicts the % ozone destruction efficiency:

% Ozone Destruction Efficiency = F(T, t, v, RH)

Where:

T = Temperature
t = Residence time
v = Linear velocity
RH = Relative humidity

## 2.3 Practical Considerations

**Effects of Catalyst Poisons**

The ozone destruction using catalytic decomposition in principle does not consume the catalytic media, as it is only intended to lowering the activation energy for the ozone molecules to break into molecular oxygen. However, it should be noted that the presence of such catalyst poisons as halogens, hydrocarbons, sulfurs, phosphorus, and nitrogen oxides will affect the efficiency of the destruction and the life of the media. Poisons should be removed from the gas stream before passing through the destruct unit to preserve and prolong catalyst life. The halogens, e.g., hydrochloric acid (HCl) or hydrofluoric acid (HF) or chlorine ($Cl_2$), heavy hydrocarbons, and sulfur and phosphorus compounds cause **irreversible** adsorption poisoning of the catalytic medium. Decomposition efficiency falls, and the catalyst ultimately needs replacement.

**Preventing Premature Catalyst Failure**

Nitrogen oxides ($NO_x$), which are formed along with ozone in corona discharge generators fed by air instead of oxygen, are also strongly adsorbed on the catalyst at room temperature. The adsorption poisons the catalyst, as described earlier, leading to destruction inefficiency. However unlike irreversible poisoning, $NO_x$ deactivation can be minimized or prevented by heating the gas stream to greater than 100 $^oC$ prior to contact with the Catalyst. If this is not done and $NO_x$ poisoning occurs, it is **reversible** by heating to over 600 $^oC$. However, this is typically not practical. Therefore as a preventative measure, it is recommended that either $NO_x$ be removed prior to catalyst contact, or the gas stream be preheated to avoid the initial adsorption.

When the ozone generators are fed with oxygen or with oxygen spiked with low volumes of nitrogen, the effect of NOx is negligible and it has no impact on the destruct efficiency.

**Heat Generation During Operation**

The energy of chemical scrubbing of ozone results in a temperature increase of the catalyst material and its container. For this reason, the catalyst bodies are “shielded” to minimize incidental touching while a catalyst is in operation. The increased temperature offers no other hazard, and in fact enables the destruction of ozone.

**Ammonia and Water Effects**

Preheating the sample to greater than 100 $^oC$ has the additional benefits of stopping both ammonia ($NH_3$) poisoning and water condensation within the catalyst bed. Liquid $H_2O$ coats the active catalyst sites and renders the catalyst inefficient. If a catalyst has been exposed to liquid water, the catalyst should be heated and dried as quickly as possible to prevent catalyst from becoming ‘caked’ which would permanently block gas flow. This process is called ‘re-generation’.

In applications where water condensation is possible, Teledyne API (TAPI) recommends the use of a coalescing filter and drain prior to the ozone destruct inlet or Thermal Ozone Destruct (TOD) modules. Consult with TAPI if water vapor or liquid water is present in the gaseous stream.

## 2.4 Ozone Destruct Models

Teledyne API offers three standard destruct system models that are described in this manual. The model of the ozone destruct system is selected based on the ozone concentration needing to be destroyed and the flow rate of the feed. All three use the same $MnO_2$ catalyst fill.

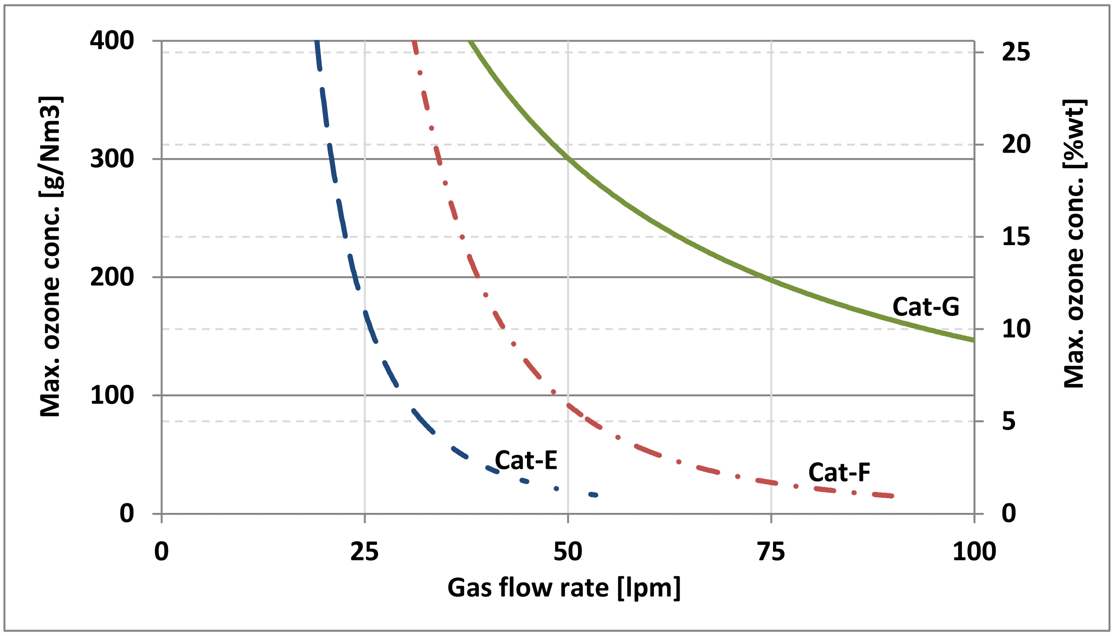


*Figure 2. CAT-x performance (dry applications)*

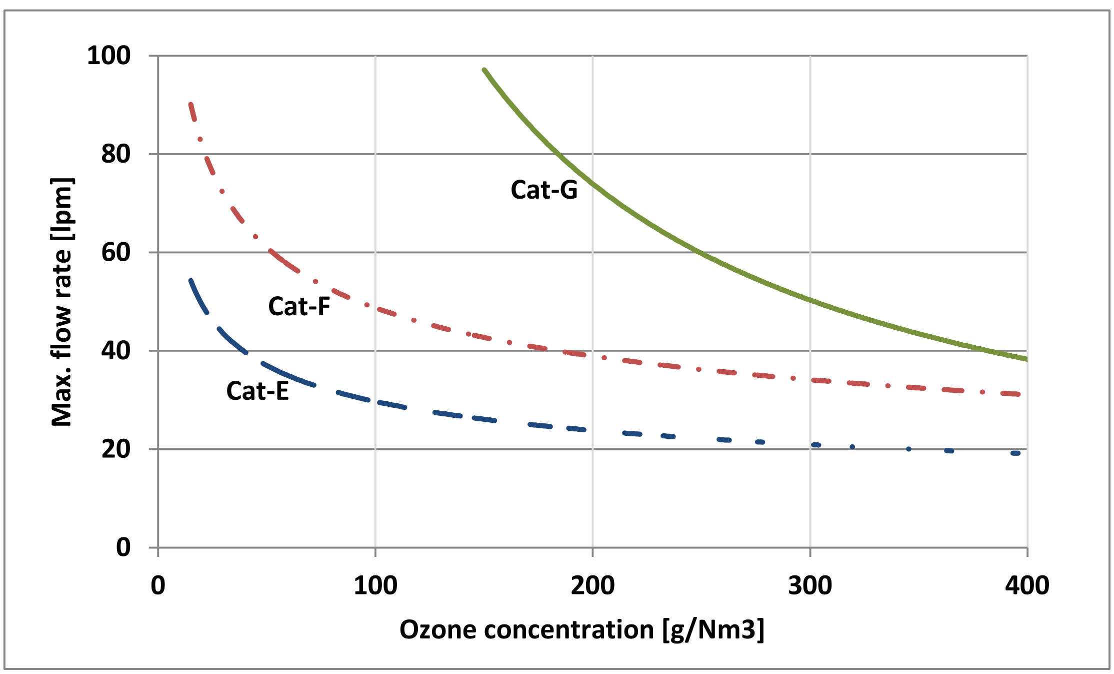


*Figure 3. Maximum flow rate (dry applications)*

## 2.5 Specifications

| | | |
|---|---|---|
| Performance/ Application | Application | Catalytic Ozone Destruct |
| | Principle of Operation | Catalytic |
| | Catalyst | Manganese dioxide based compound |
| | Capacity | Refer to charts. |
| | Outlet Concentration | < 0.1 ppm |
| | External Temperature | < 30°C |
| | Temperature Increase | < 70°C absolute temperature increase due to heating |
| Materials | Housing | Stainless steel<br>Catalyst body is SS and welded |
| | Inlet/Outlets | Standard fittings:<br>Cat E and Cat F: ½" stub<br>Cat G: ¾" VCR® compatible fittings<br>Other compression or VCR fitting options are available. Please contact the factory for information. |
| | Heat Protector | Aluminum outer protection shield |
| Maintenance | None | |
| Lifetime | 3 to 5 years or longer | |

*Specifications subject to change without notice*

### Pressure Drop

Pressure drop on all three catalyst models is less than 1 PSI at flow rates up to 60 lpm and less than 5 PSI at flow rates up to 100 lpm.

# 3 Installation

## 3.1 Dimensions and Mounting:

Refer to the dimension drawing below and on the next page for installation requirements. Please allow appropriate clearance around the device for maintenance/changeout access.

Actual fittings will vary with installation, and are not included explicitly in the figures.  However, the dimensions from seal face to seal face adheres to the dimensions provided (18.05” for CAT-E, 26.55” for CAT-F).

**DANGER**

**LEAK-THROUGH HAZARD!**

**The units should also ALWAYS be mounted vertically with the gas inlet at the bottom. Labels are provided to indicate to the user the inlet side of the unit.**

## CAT-E Dimensions

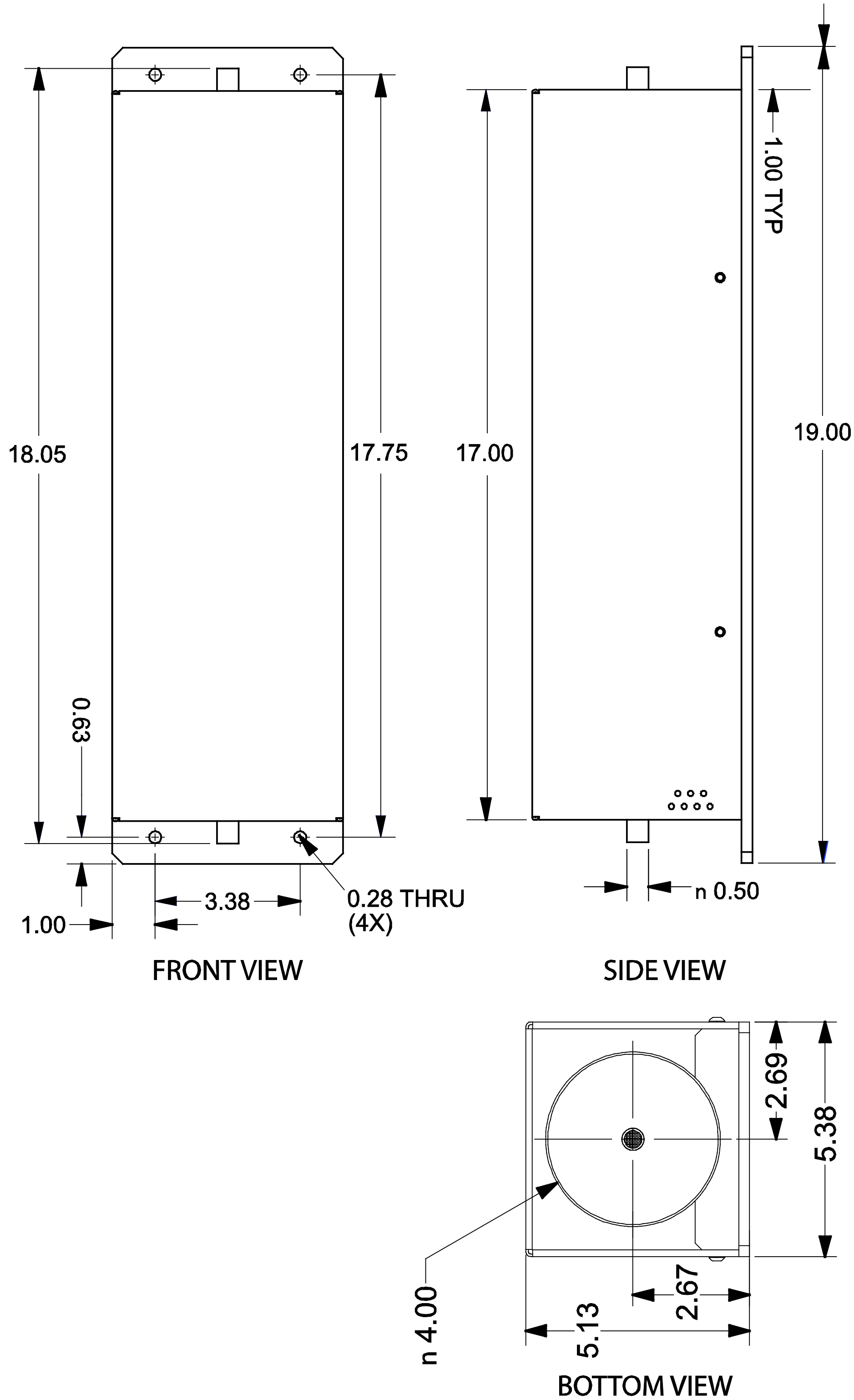


*Figure 4. CAT E Dimensions*

## CAT-F Dimensions

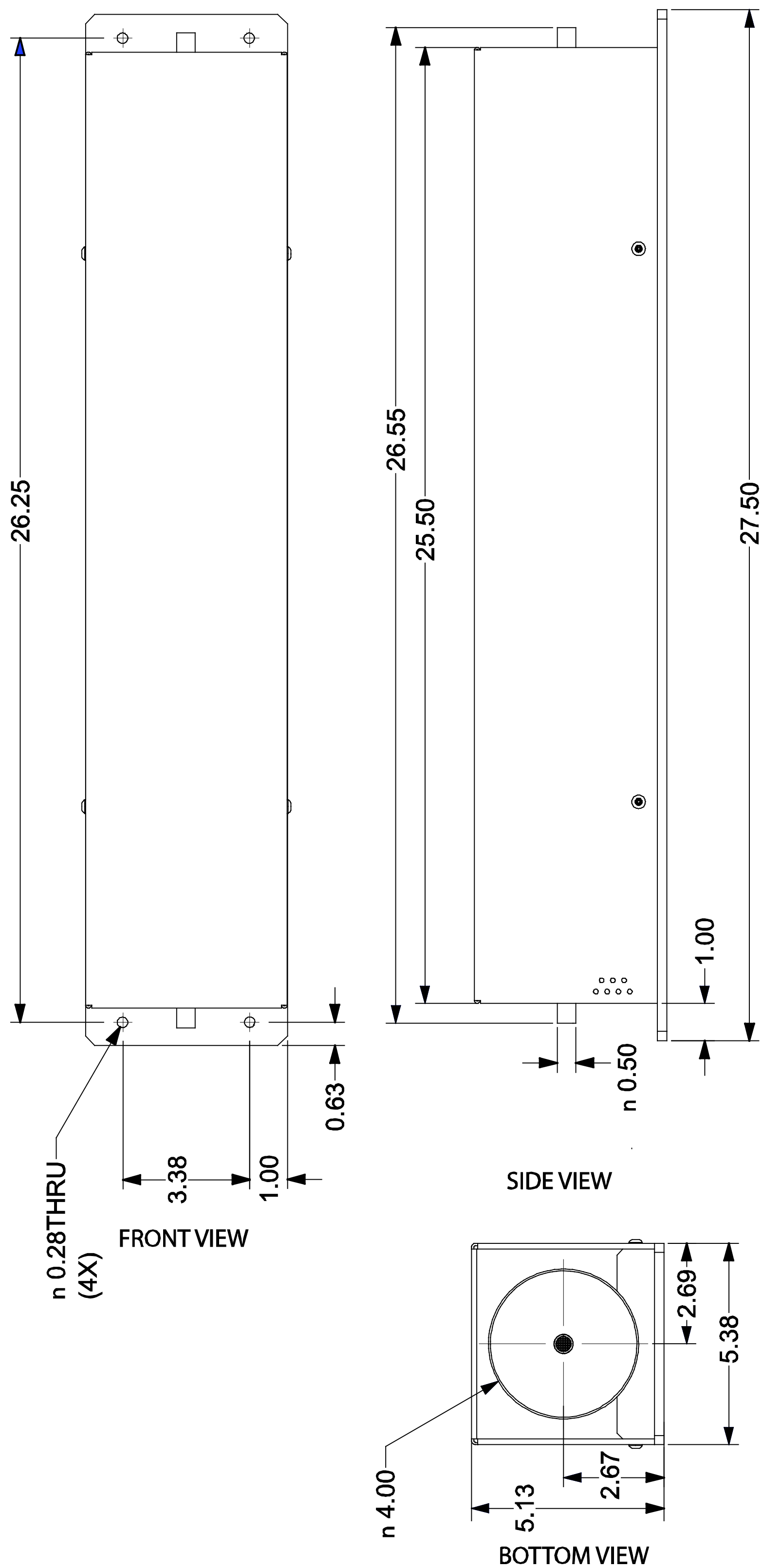


*Figure 5. CAT F Dimensions*

## CAT-G Dimensions

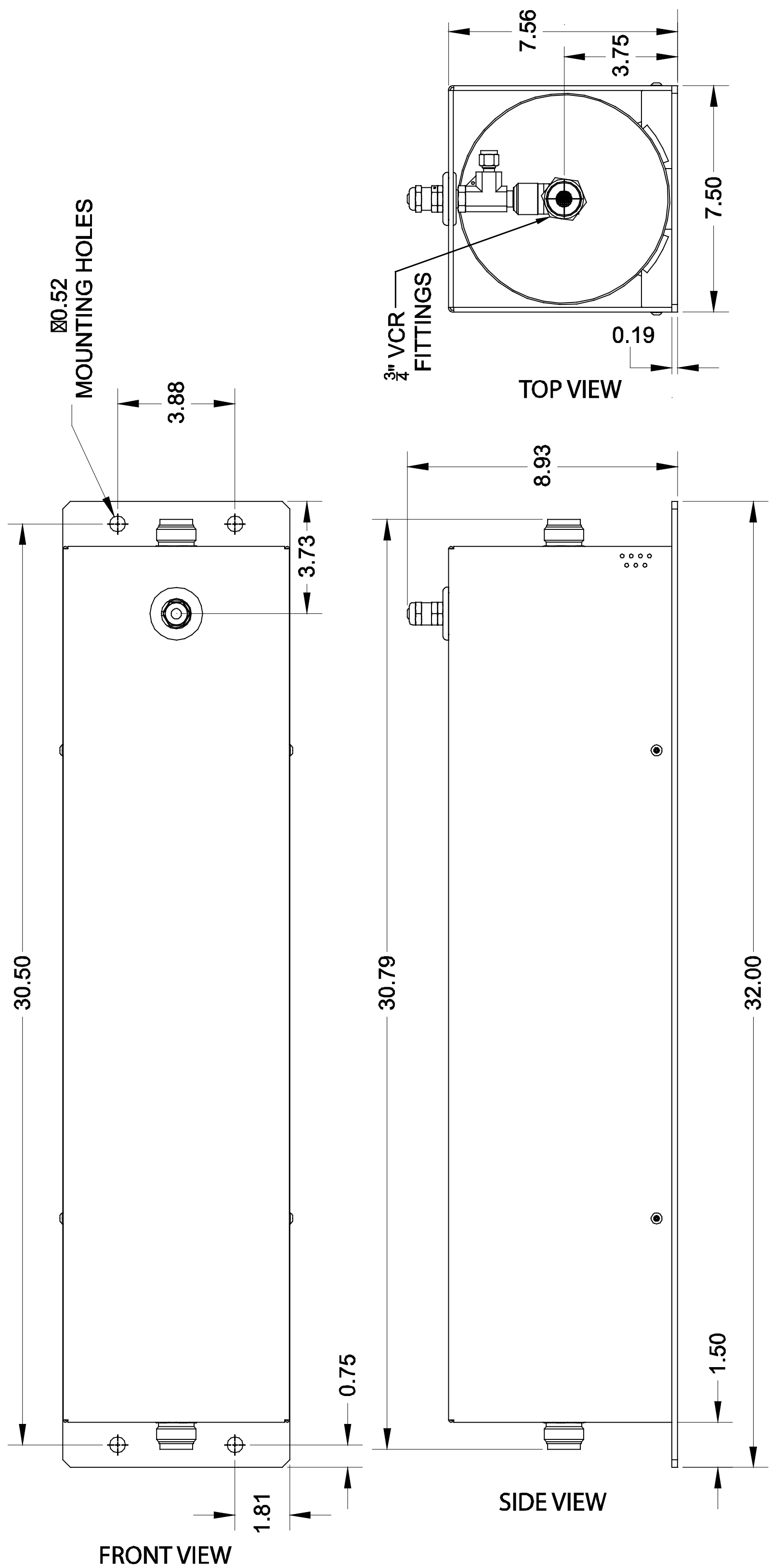


***Figure 6. CAT G Dimensions***

## 3.2 Installation Procedure

1. Plan sufficient clearance space around the device:

   Leave sufficient space around the device to allow connections to the unit, and the ability to remove the unit.

   **Special Clearance Space Notes:**
   All units should be installed in an environment that allows free convection of air. Never block any vents. Never locate the equipment next to high heat generating equipment. Never locate the unit next to combustible materials.

2. Mount the unit in a vertical position.
   Refer to the unit dimensions.

   Always mount the catalyst vertically. The destruct agent is a granular powder that will fill the volume of the catalyst with a small gap at the top. In this orientation, Ozone cannot bypass the destruct agent. If the catalyst were mounted horizontally, the Ozone could bypass the destruct agent along the top of the cylinder.

3. Make gas connections using industry-standard fitting techniques.

**⚠ WARNING**

**Leak Hazard!**

Materials in contact with high concentrations of ozone should be suitable for such use. Stainless Steel (316L), Teflon®, and Chemraz® are recommended.

**DO NOT use silver plated gaskets for VCR fittings** since they catalyze the decay of ozone severely. **Use non-plated stainless steel gaskets only!**

4. For systems with pressure relief valves:

   The Pressure Relief Valve protects against accidental over-pressure. By mounting the catalyst vertically, with the pressure relief valve on top, the gases escaping through the pressure relief valve will not contain Ozone, under normal circumstances. One possible situation which might be considered normal is when the exhaust port of the catalyst is shut off by a process valve. This is also called dead-heading, resulting in an immediate rise in pressure caused by the flow of gases in the process lines. The pressure relief valve will protect the catalyst from physical damage due to the over-pressure.

   The pressure relief is set at the factory at 30 psig.