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OVEN 101 – The basics of specifying industrial ovens.

- GENERAL
  Industrial ovens are required in a wide range of applications. Most manufacturing processes require some form of heat process. These processes include the following:

  Aging
  Annealing
  Curing
  Drying
  Hardening
  Heat Treating
  Powder Coating
  Sintering
  Solvent Venting
  Sterilization
  Stress Relief
  Tempering

  These processes are done throughout industries. Some of the more common industries are:

  Aerospace
  Automotive
  Defense Contractors
  Electronics
  Metal Work
  Mining and Drilling
  Painting
  Pharmaceutical
  Plastics

  Industrial heat processing requirements are divided into two categories: oven and furnace. An oven operates in a range of temperatures from ambient to 1250°Fahrenheit. A furnace operates above 1250°Fahrenheit. As the temperature increases, different characteristics change with the oven design.

- TYPES
  There are several classifications of ovens that have developed over the course of the past 100 years.
  a. Bench Oven
     This oven is generally designed for an industrial setting with heavy duty components. It is named due to its location on a work bench in a factory. Therefore, it is small in scope. This classification usually stops when the unit gets to be 27 cubic feet of interior space.

  b. Lab Oven
     This oven is generally used in a laboratory setting. Therefore, it has slightly different requirements than a bench oven, but is similar in size. Lab ovens usually are not designed to be handled roughly and are more like office equipment in terms of durability. Many have features that would be beneficial to research, including stainless steel interior chambers to prevent corrosion from unknown materials, variable exhausts, programmable controllers, and other components that can easily be modified to suit the unique application.

c. Cabinet Oven
This industrial oven can range from 15 cubic feet to over 100 cubic feet of work space. The name comes from the fact that the unit is loaded from the front, like a cabinet. The floor is usually fully insulated. Many times the side walls have shelf slides to accept loading shelves.

d. Truck Oven (also called Truck-In or Walk-In)
This is the most common industrial oven and offers a great deal of flexibility. It is designed to be loaded with a cart (truck). The truck is loaded with product outside the oven and rolled into the chamber for processing. The floor of the oven may be equipped with recessed tracks on an insulated floor with the tracks matching the wheel spacing on the truck. Or the oven may have a full plate floor to allow the truck to be wheeled into place without obstructions.

e. Conveyor Oven
This oven type is usually the most complex in its design. It is used in a full factory setting and, many times, is coupled with automated processes feeding the unit or taking parts from the unit.

f. Top Load Oven
This oven operates with the top of the oven on a hinge to allow crane loading.

g. Vertical Lift Ovens
Often used in raw material hardening, sintering or other similar operations, the oven itself is on a vertical lift hoist. The entire oven is raised up; the product is put in place, and the oven is lowered over the product to begin the process. It is used with very heavy loads

h. Sterilizers
Used in medical and pharmaceutical fields. sterilizers offer a full clean room application in which the oven is used to kill the pyrogens on glassware.

i. Granulation Dryers
Used in pharmaceutical manufacturing for drying of powdered materials, granulation dryers can be used with flammable and non-flammable solvents. (This type of oven is becoming more rare in its application as other technologies, such as fluid bed dryers, have become more prevalent and are easier to integrate into a production line.)

- SPECIFYING A NEW OVEN
  a. PROCESS
  When thinking about an oven design, process is the most important section to consider. If the oven is not designed for the specific process being developed, it may never meet the needs of the user.

  The process considerations begin with the orientation of the product being processed.

What is trying to be accomplished?

Are the parts oriented in a manner that airflow will not reach all pieces?

How large is the batch or individual piece?

What is the piece rate?

How long must the part be at temperature?

What tolerance do the parts have for temperature variance?

The more information gathered about the process will provide for a better design. Some specific questions about the process are listed below in more detail.

i. Drying
Many applications require that a material is dried. (Whether there is a non-flammable solvent, oil, or water present, or maybe the upstream process imparted solvents on the parts that now need to be baked out before they can move further in the process.) Regardless of what is being dried, the oven will need to be designed to suit. For example, the exhaust will need be sized to handle the material being dried off.

The main questions for this application are as follows:
1. What product is being dried off?
2. How much of this product will be loaded into the oven?
3. What time frame is required to complete the drying operation?

NOTE: Should the material being dried be a flammable solvent, the unit will need to be rated to meet NFPA86 Guidelines for Solvent Venting Ovens. Compliance with this guideline includes the following items added to the oven:

a. Powered exhaust – solvent capacity for the exhaust capacity will be labeled on the face of the unit. The process cannot exceed this stated level of solvents.
b. Purge Cycle – The control system shall include a purge timer to ensure that after the process heat has been turned on, the exhaust must make the necessary air exchanges inside the oven before engaging the heaters. This prevents any latent solvent build-up from causing an explosion when the heat is engaged.
c. Non-Sparking Fans – The circulation and exhaust fans will be required to be non-sparking. This normally means that the fan housing or slinger ring is of a different material than the fan blades.
d. Pressure Relief Panel – A panel must be sized on the oven that will account for an unexpected relief of pressure inside the oven (explosion). This panel will prevent the unit from becoming a bomb. The location of this panel can be specific to a particular plant (depending on safety considerations). However, the most common application is to have the

main oven doors be pressure relief and they are held together by restraining chains to prevent them from opening fully. This will usually send the pressure wave upward.

ii. Inert Atmosphere
This is another unique requirement to a specific process. This is often used when processing a raw material into a designed component. If the material is subject to oxidation and a certain temperature, the process must be completed in an inert atmosphere (nitrogen or argon are the most common gases used). This will require special gasketing, automated valves, purge cycles, and special controls.

b. TEMPERATURE CHARACTERISTICS
Unless there is a process need to cause this information to change, the construction will be as follows:

i. UP TO 450ºF
- Interior – aluminized steel (a steel coated with an aluminum-iron alloy coating; prepared by dip-coating and diffusing aluminum into steel)
- Insulation thickness – 3” walls and ceiling, 3” floor (if applicable)
- 450ºF – silicone P Gasket

ii. UP TO 650ºF
- Interior – aluminized steel
- Insulation thickness – 4.5” walls and ceiling, 3” floor (if applicable)
- 650 ºF – stainless steel core wrapped with ceramic core

iii. UP TO 800ºF
- Interior – aluminized steel
- Exterior – face will be painted high temperature black to prevent burn off when the door is opened.
- Insulation thickness – 6” walls and ceiling, 3” floor (if applicable)
- Stainless steel core wrapped with ceramic core

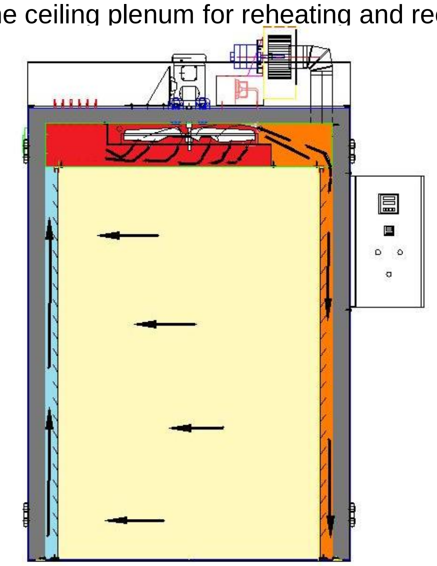
iv. UP TO 1000ºF
- Interior – 304 stainless steel (aluminized steel will lose its coating at about 850 ºF)
- Exterior – face will be painted high temperature black to prevent burn off when the door is opened.
- Insulation thickness – 8” walls and ceiling, 3” floor (if applicable)
- Ceramic cloth with stainless steel mesh core gasket

v. UP TO 1250ºF
- Interior – 304 stainless steel
- Exterior – face will be painted high temperature black to prevent burn off when the door is opened.
- Insulation thickness – 8” walls and ceiling, 3” floor (if applicable)
- Ceramic cloth with stainless steel mesh core gasket

- NOTE: A mechanical convection oven may still be used up to 1400ºF. However, the air becomes very thin to recirculate. This would be evaluated on a case-by-case basis. If this design is to be carried out, the change would require a type 309 stainless steel interior.

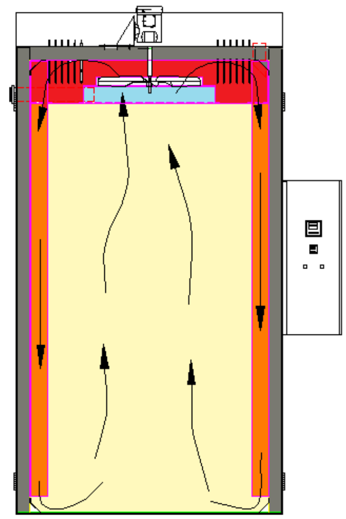
c. AIRFLOW
The airflow for a process is critical to the proper heat transfer to the parts in production. Depending on the layout, any of the following orientations may be effective in best transferring heat. As it stands, there is no set guideline. Effective engineering understanding of the parts and how they are loaded will allow the user to make the best choice.

i. Horizontal
The air moving equipment and heating elements are in a plenum on top of the unit. Air pressurizes one side wall, flows across the heat chamber, to a negative pressure wall on the opposite side, then to the ceiling plenum for reheating and recirculation.



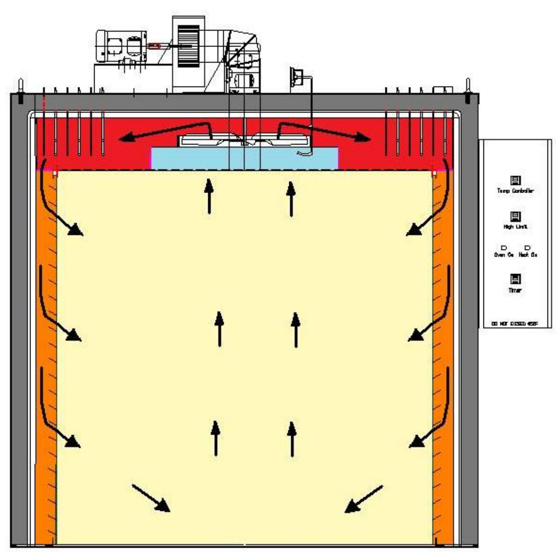
Front View

ii. Vertical
The air moving equipment and heating elements are in a plenum on top of the unit. Air enters the chamber near the bottom of each side wall, flows up through the product to the ceiling panel, where it then passes over the heaters and fan to be recirculated.



Front View

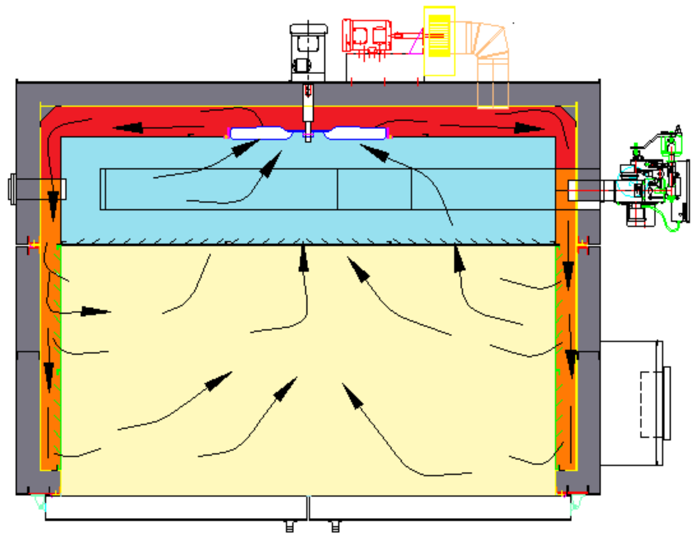
iii. Horizontal / Vertical
The air moving equipment and heating elements are in a plenum on top of the unit. Air enters the chamber across the whole wall on each side of the chamber, flows up through the product to the ceiling panel, where it then passes over the heaters and fan to be recirculated.



FRONT VIEW

iv. Compound Horizontal

The air moving equipment and heating elements are in the rear of the unit. Air enters the chamber each side wall either over the full height and depth of the wall or only near the front (depending on configuration of the load), flows back through the chamber to the back wall, where it then passes over the heaters and fan to be recirculated.



PLAN VIEW

d. TEMPERATURE UNIFORMITY

Many times a customer's process will require minimal tolerance for differences in temperature throughout the chamber. This is called temperature uniformity. Typically, it is specified as a ±xºF at a temperature setpoint of XXXºF. Normally, the temperature uniformity of ±5ºF at 450ºF is attainable with very little engineering work.

A temperature uniformity specification will normally create a requirement for the factory to perform testing on the unit prior to shipping to make sure that the specification is met. This causes an increase in price to accommodate the labor to perform the testing.

The specification that is least expensive to perform and test is a nine point test within an 80% cube of the interior space with the chamber empty.

Other types of specification:

- The same test with empty shelves / trucks in the oven
- A twelve point test (or more points
- A test with the product in place

e. AIR VELOCITY

To maintain temperature uniformity in the chamber, an air velocity is required to 150-200 feet per minute. This will translate to the recirculation air volume being calculated using that air velocity and the square footage of the pressurized feed wall.

f. AIR ADJUSTMENT
The standard inlet and exhaust wall will be configured with adjustable louvers. The louvers are pre-punched “C” shaped holes in the walls. The “C” shape allows them to be pushed to full open, left full closed, or somewhere in between. This adjustment allows the unit to be tuned for airflow to move more or less to different parts of the chamber.

g. GENERAL PLENUM / AIR CONFIGURATION
All oven units will be have a negative side heat input in the plenum. The heating system shall be on the negative side of the fan, thus drawing air across the heater, spun through the fan, and then on to the pressure wall for distribution to the chamber. This ensures that the heated air is properly mixed so there is even heat in the pressurized air.

h. HEAT INPUT
There are generally three types of heat inputs.

i. Electrical Resistance
- Least expensive capital investment
- Normally most expensive per cycle to operate
- High Full Load Amperage Loads for oven system requires adequate facilities

ii. Flammable Gas (Natural Gas or Propane)
- High capital cost
- Low operating cost
- Can be fired directly (gas flame is in the plenum with open flame) – imparts product of combustion to the process.
- Can be indirect fired (gas flame is in heat exchanger tube) – Less efficient, more expensive, but keeps product of combustion out of the process

iii. Steam
- Mid range capital cost
- Only viable for lower temperatures
- Requires significant facility systems (Steam Line, Condensate Drain)

i. FACILITY REQUIREMENTS

i. ELECTRICALLY HEATED OVENS

The main facility requirement associated with an electrically heated oven will be the electrical line coming into the unit. Many times the amperage rating for the oven will be very high in relation to similar equipment on the plant floor. Many times, the oven must be designed around the incoming power capacity. The total Full Load Amps (FLA) will include the heat input, motors (all motors, including all circulation motors and exhaust), and control circuit. Once the FLA has been determined, add a 20% safety factor to determine the recommended breaker size.

- AMPERAGE CALCULATIONS FOR ELECTRIC OVENS
  - HEAT INPUT

*SINGLE PHASE POWER*

$$\underline{\text{watts of heat input} \;/\; \text{voltage} = \text{amperage}}$$

*THREE PHASE POWER*

$$\underline{\text{amperage for single phase} \;/\; 1.73\ (\text{correction factor}) = 3\ \text{phase amperage}}$$

  - MOTOR INPUT

**AC Single Phase Motors**

| Horse-power | 115v | 200v | 208v | 230v |
|---|---|---|---|---|
| **Amperes** | | | | |
| **1/6** | 4.4 | 2.5 | 2.4 | 2.2 |
| **1/4** | 5.8 | 3.3 | 3.2 | 2.9 |
| **1/3** | 7.2 | 4.1 | 4.0 | 3.6 |
| **1/2** | 9.8 | 5.6 | 5.4 | 4.9 |
| **3/4** | 13.8 | 7.9 | 7.6 | 6.9 |
| **1** | 16 | 9.2 | 8.8 | 8.0 |
| **1-1/2** | 20 | 11.5 | 11 | 10 |

| | | | | |
|---|---|---|---|---|
| **2** | 24 | 13.8 | 13.2 | 12 |
| **3** | 34 | 19.6 | 18.7 | 17 |
| **5** | 56 | 32.2 | 30.8 | 28 |
| **7-1/2** | 80 | 46 | 44 | 40 |
| **10** | 100 | 57.5 | 55 | 50 |

| AC 3 Phase | | | | | | |
|---|---|---|---|---|---|---|
| Horse-power | 115V | 200V | 208V | 230V | 460V | 575V |
| Amperes | | | | | | |
| 1/2 | 4.4 | 2.5 | 2.4 | 2.2 | 1.1 | 0.9 |
| 3/4 | 6.4 | 3.7 | 3.5 | 3.2 | 1.6 | 1.3 |
| 1 | 8.4 | 4.8 | 4.6 | 4.2 | 2.1 | 1.7 |
| 1-1/2 | 12.0 | 6.9 | 6.6 | 6.0 | 3.0 | 2.4 |
| 2 | 13.6 | 7.8 | 7.5 | 6.8 | 3.4 | 2.7 |
| 3 | -- | 11.0 | 10.6 | 9.6 | 4.8 | 3.9 |
| 5 | -- | 17.5 | 16.7 | 15.2 | 7.6 | 6.1 |
| 7-1/2 | -- | 25.3 | 24.2 | 22 | 11 | 9 |
| 10 | -- | 32.2 | 30.8 | 28 | 14 | 11 |
| 15 | -- | 48.3 | 46.2 | 42 | 21 | 17 |
| 20 | -- | 62.1 | 59.4 | 54 | 27 | 22 |
| 25 | -- | 78.2 | 74.8 | 68 | 34 | 27 |
| 30 | -- | 92 | 88 | 80 | 40 | 32 |
| 40 | -- | 120 | 114 | 104 | 52 | 41 |

- CONTROL CIRCUIT INPUT

The control circuit can apply an additional 5 to 10 amps to the total full load amps.

ii. GAS HEATED OVENS
Natural gas or propane heated ovens will provide a lower power requirement. The main concern with natural gas heated units are the gas train design. Different insurance groups require different components in the train. The customer must specify whether the design is to match an IRI train or a FM train.

iii. INSTALLATION OBSTACLES
An industrial oven can be much larger than a customer will expect. The interior chamber dimensions are normally much smaller than the overall dimensions required. The plenum space, insulation thickness, control panel size, and motor overhang can significantly add to the overall dimensions of any unit. Normally, the oven will be shipped fully assembled on a skid. This will also add to the overall dimension that must traverse the facility.

The installation path from the receiving dock to the final installed location must be determined. Any pinch points for turns, doorways, and all ceiling heights should be measured to determine any restriction on the size of the unit. If necessary, the oven can be shipped on its side, with a control panel removed, or motors removed, or with a modular construction technique. Once the restriction has been determined, the most economical way to work around the obstruction will be determined.

j. INSTRUMENTATION

i. CONTROL

1. SINGLE SETPOINT CONTROLLER
The single set point controller is the base oven controller. It takes a temperature input and sends a signal to the heating system. If the input is below the set point the unit will call for heat. It will continue to call for heat until the set point temperature has been reached. Once at temperature, the controller will monitor the chamber temperature and call for heat as the temperature falls.

Depending on the controller selected, the unit will have settings to determine temperature overshoot at the set point or proportional output to smooth out the chamber temperature curve for the whole process.

2. PROGRAMMABLE TEMPERATURE CONTROLLER
A programmable temperature sensor will operate in a similar fashion a single set point controller. However, the programmable controller will allow for a temperature versus time graph for the process. It can control "RAMP" cycles by allowing for a set increase or decrease in temperature during a set time frame (e.g. 3 degrees per minute). It can also control the amount of time the process stays at a certain temperature "SOAK."

ii. HIGH LIMIT THERMOSTAT
Each oven must be provided with an independent high limit thermostat for safety. The thermostat has its own temperature input, It is set at a point above the maximum set point of the unit. Should there be an issue with the main controller and the oven reaches the high limit set point, the heating source will be shut down. This protects the equipment and the users.

iii. HEAT CONTROL
The oven heat control will be performed with no mechanical contacts, ensuring safer operation and making for better temperature control. The control will be performed with solid state relays or silicone controlled rectifiers.

A **solid state relay (SSR)** is an electronic switching device in which a small control signal controls a larger load current or voltage. It comprises a voltage or current sensor which responds to an appropriate input (control signal), a solid-state electronic switching device of some kind which switches power to the load circuitry either on or off, and some coupling mechanism to enable the control signal to activate this switch without mechanical parts.

A **silicon-controlled rectifier** (or **semiconductor-controlled rectifier**) is a four-layer solid state device that controls current.

iv. SWITCHES
The oven at a minimum should have a switch to engage the circulation system and a separate switch to engage the heating system. The number and functions of the switched is often determined by the process and there is a great deal of flexibility in the design.

v. DIFFERENTIAL PRESSURE SWITCHES
As a safety measure, the circulation fan(s) must be equipped with a differential pressure switch with the differential inputs set up across the positive and negative side of the fan. This switch will keep the heating system engaged while there is proper differential pressure. Should the switch see a loss of pressure, meaning the fan is not circulating air, the heating system will disengage.

vi. TEMPERATURE SENSING

Normally, the temperature sensor for the oven will be done in the pressure wall near the chamber. Normally, a thermocouple will be located during the testing operation of the unit to provide accurate control of the chamber temperature. The thermocouple is calibrated with the instrument controlling the system. Many different types of thermocouples are used for different applications. A list of thermocouples is shown below. In addition, other sensing devices, such as RTD's can be used to signal the controller.

| Thermocouple Type | Names of Materials | Useful Application Range |
|---|---|---|
| E | Chromel (+)<br>Constantan (-) | 200-1650F |
| J | Iron (+)<br>Constantan (-) | 200-1400F |
| K | Chromel (+)<br>Alumel (-) | 200-2300F |
| N | Nicrosil (+)<br>Nisil (-) | 1200-2300F |

| | | |
|---|---|---|
| T | Copper (+)<br><br>Constantan (-) | -330-660F |

vii. DOOR SWITCH
This simple mechanical switch can be mounted on the unit to sense whether the door is opened or closed. The most common application is turn the heat off when the door is opened. The state of any system (circulation or exhaust) can also be changed when the door is opened.

viii. RECORDING
As a means of quality control, some ovens are equipped with a temperature recorder. The recorder will track the chamber temperature over the course of the process and log it for future reference. The recorder may be as simple as a single pen on a circular chart or may be as complicated as a 20 channel recorder tied to a computer system. Each recorded point will typically have an independent temperature sensor.

ix. AMP METERS
On some occasions, the monitoring of the amperage draw of the electrical heating elements may be required. An amp meter across each leg of the three phase power will continually indicate the power being pulled through the circuit. Should one of the legs begin pulling a lesser amount of current, one of the heating elements may have burned out.

k. SPECIAL CHARACTERISTICS

i. EXPLOSION RESISTANCE
An oven may be running the process in an environment that is rated to be explosion proof. This will require several differences in design that will cause a significant increase in cost. All electrical connections will be need to be made in an explosion resistant junction box, all motors will need to be rated XP, and the control panel typically will be in another room outside the rated environment. Should the control panel be mounted in the rated room, a purged box will be required. The purged box will provide a positive pressure to the control panel eliminated the possibility that any flammable material can be drawn into the control panel.

| **CLASS** | |
|---|---|
| Class | Definition |
| Class I | Are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. |
| Class II | Are those which are hazardous due to the presence of combustible dust. |
| Class III | Are those which are hazardous due to the presence of easily ignitable fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the air in quantities to produce ignitable mixtures. |

| DIVISON | |
|---|---|
| Division I | Locations in which hazardous concentrations in the air exist continuously, intermittently, or periodically under normal operating conditions. |
| Division II | Locations in which hazardous concentrations are handled, processed, or used but are normally within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown. |
| **GROUP (CLASS I)** | |
| Group A | Atmospheres containing acetylene. |
| Group B | Atmospheres containing hydrogen, or gases (or vapors) of equivalent hazard, such as manufactured gas. |
| Group C | Atmospheres containing ethyl-ether vapors, ethylene or cyclo propane. |
| Group D | Atmospheres containing gasoline, hexane, naptha, benzine, butane, alcohol, acetone, benzol, lacquer solvent vapors, or natural gas. |
| **GROUP (CLASS II)** | |
| Group E | Atmospheres containing metal dust, including aluminum, magnesium and their commercial alloys and other metals of similarly hazardous characteristics. |
| Group F | Atmospheres containing carbon black, coal, or coke dust. |
| Group G | Atmospheres containing flour, starch, or grain dust. |

i. COOLING

Process requirements or production speed may facilitate the need for a process to have a cooling cycle. This can be accomplished in several different ways.

a. Exhaust Fan

The simplest form of cooling would be to initiate a higher exhaust rate after the heating cycle has ended. This is accomplished with a powered exhaust turning on. Or if a low exhaust rate is required during the heat cycle, a second damper position for cooling can be used and the controller will switch the damper position.

This solution will cool as quickly as physics will allow with no means for control.

b. Exhaust Damper

A way to introduce cooling from the controller is with a motorized damper. The damper can be controlled on the percentage opened by the controller to try and control the cool down rate. This will not provide accurate control, but can be used to bring the temperature down in a controlled manner.

c. Cooling Gas Injection
A third way to bring the temperature down is with an injection of a cooling gas (e.g. nitrogen). The injection is intiated with an on/off solenoid valve or a modulating valve that will control a percentage of input through the valve. The modulating valve can be used to control a rate of reduction in temperature.

d. Cooling Coil
The most effective way to maintain a temperature ramp at any point in the process. A chilled water coil mounted in the plenum can circulate cooling water with a modulating valve controlled by the controller. This coupled with heat control can actively maintain the temperature required by the process.