



# **Equipment Considerations for Steam Heat Treatment as a part of Integrated Pest Management**

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## Preface

The Food Industry has successfully utilized heat treatment for insect control for some time at several plants. However, the use of chemical fumigants to accomplish this task has been much more predominant. Recent pronouncements related to the Montreal Protocol concerning the use of specific chemicals around food and the release of these chemicals to the atmosphere have focused increased attention on the use of heat as an alternative.

This paper addresses Steam Heating Equipment and the Design and Application considerations that a successful steam heat treatment installation requires.

## The Objective and Constraints of Steam Heat Treatment

Of course, the main objective of any integrated pest management program is to eliminate the living and egg form population. With steam heat treatment, however, there are several other considerations that must be taken into account. An ***Integrated Heat Treatment Audit*** by a team consisting of proven pest management personnel and factory trained steam/energy specialists should be utilized.

Some additional considerations are:

1. Although the entire floor area and surfaces must be brought up to a terminal temperature (125°F +), heat must first be concentrated on the places that insects are most likely to be found.
2. The temperature needs to be brought up to terminal temperature, as quickly as possible (typically 10°F per hour from ambient. Varies by location and structure type.)
3. The maximum space temperature must be controlled to avoid damage to buildings, equipment and systems. All aspects of construction, including fire suppression and even lighting enclosures need to be reviewed before proceeding.
4. Delicate equipment, such as electronics, need to be evaluated for ability to withstand the higher ambient conditions, higher static potentials, and lower relative humidity.
5. Humidity level controls may need to be considered in areas (especially older structures) where wood products are still part of the construction or equipment.
6. The steam heating equipment must be installed and operated properly to ensure adequate heat up and long, reliable life.

The following items address several of these objectives in detail.

## Types of Steam Equipment Used

The types of steam heat treatment equipment in use are:

1. **Permanently installed Steam Unit Heaters.** Where the site facilities allow reasonably low mounting of the unit heater and they can be positioned so as not to interfere with normal operations of plant and equipment. They provide the best option for correct placement.
2. **Portable Steam Unit Heaters** for cool spot or small area coverage. Portables offer more precise direction of airflow. Portables may allow heat to be directed to locations where a permanently mounted unit would get in the way of normal operations. Unit heater placement is still an art form, and often portable units are added as an afterthought to handle cool spots after some test heat treatment is obtained. Portable equipment should be supplied with complete packaging including, temperature control devices, isolation/disconnects, drainage (trapping considerations), condensate return support as needed, structurally sound cart design with wheel construction suitable for industrial and high temperature usage, ability to move through doorways or elevators, minimum 50 ft. of properly selected steam and condensate hose, and 50 ft. of appropriately sized electrical cable. Cart mounted racks should be included. Ability to lift and stack 2 units on top of each other to reduce storage space when not in use should be considered.
3. **Permanently installed large capacity fan/coil units** are also an option. These units may actually combine several permanently mounted propeller fans behind a single, larger finned steam coil, in a single unit. Or they may utilize a single or dual centrifugal fan on a common shaft. They fit best where there are large open areas to be heated and are usually the most economical choice (when numbers of units need to be reduced due to budget constraints).

## Fan Selection for Insect Control Application Comparison Table

Fan Type	Air Volume	Noise	Pressure	Repair	Flexibility	Efficiency	Capital Cost	Operating Cost \$(1)	Servicing
<b>Centrif.</b>	Wide range	Very low	Wide range	Not simple	Medium	Very high	High	Low	Medium
<b>Vane-axial</b>	Wide range	Medium	Low-med.	<b>Complex</b> (2)	High	Low-med.	High	Medium	Critical
<b>Axial</b>	High	High	Low-med.	Very simple (reliable)	High	Low-med.	Low	Medium	Minimum
<b>Insect Control</b> (3)	High	Not critical	Low (1 row coil)	Reliable direct drive	Not critical	<b>Not critical</b> (4)	Low	Not critical	Minimum

1. Operation cost considers the use of electricity per cfm delivered.
2. The repair and service cost of a variable pitch vane axial fan are out of range vs. a direct drive axial fan.
3. Insect control applications require fans delivering high air volume at low pressure with high reliability.
4. The efficiency becomes of secondary importance due to the overall number of hours in operation.

### Fan (only) Assistance to Circulation

Coverage can be achieved with unit heaters better than with other means. Unit heaters utilize high volume axial type (propeller) fan designs, with high CFM and High Throw/Spread capabilities. The chart (above) illustrates some reasoning for selecting axial fan type Steam Unit Heaters specifically for Steam Heat Treatment applications.

**Circulating Fans** – When ceilings are high, circulating fans can be installed to drive the hot air at the ceiling back to floor level. Utilizing permanently mounted Unit Heaters without heating cores and Axial Fan / Large Air Volume Capacity work best. Air temperatures can reach 170°F or higher at these levels if left to stratify. The heat has been paid for, so to ensure it is circulated to the best point of use. Some small portable floor mount units may also be utilized for lower level poor air circulation areas.

**Use of Existing Air Moving Equipment** – An evaluation of currently installed air moving equipment which will allow for RECIRCULATING AIR (not outside air) and can operate in the higher temperature environment will assist in air rotation and agitation. Consult with equipment manufacturers and suppliers to confirm operating conditions in high temperature environments. This can reduce capital equipment costs.

**Special Discharge Nozzle Designs** – Special Discharge Nozzles designed to fit on the outlet side of steam unit heaters (primarily on portable units) can be developed for directing air into custom openings (access tubes, small diameter openings in equipment, multiple directional requirements for specific spot heating, etc.).

### Placement Recommendations

Steam Heating Equipment should be positioned for discharging the heated outlet air as close to the floor as possible. Positioning discharge louvers for output at the floor, adding modulating dampers for mixing the air, and drawing cooler air with louvered intakes at floor level may improve lower level heat control. Heat will rise when introduced into a colder area. The lower the equipment and the lower the targeted discharge the more heat will find its way to the floor. Ensure designs utilizing proper sizing of steam unit heaters to avoid high discharge temperatures. (See subsequent sections.)

The units should be placed so that air is directed toward the locations most likely to harbor the targeted insect groups. Be sure to open up all production related equipment, where possible, for better access to the heated air. Some of these directional recommendations are:

1. Under Equipment
2. Behind & Between Storage Bins and Tanks
3. Near Material Hoppers
4. Into Chutes and Conveyor runs
5. Down stair wells on multi-floor applications

Attention should be paid to the location of the heaters regarding obstructions to air flow from conveyors, cookers and other such equipment.

If possible, when accomplishing the above, make sure air is directed toward walls exposed directly to outside conditions. Since heat loss is greater there, we want to keep outside walls as warm as possible. Often there is an option to either direct the air away from or toward outside walls. Always endeavor to take the latter option for best results.

## Control of Temperature

As stated earlier, consideration must be given not only to raising space temperatures but to controlling the heat to prevent temperatures from becoming too high. Placement of temperature sensing/transmitting devices has become more of an art form than a science as relates to Heat Treatment. Multiple point placement of temperature sensing/transmitting devices controlling several individual or groups of Steam Unit Heaters will result in more uniform coverage. A temperature control valve mounted on the steam inlet to the heater(s) with self-contained temperature sensing device and capillary to the control valve may be the least expensive approach to achieve some accuracy in temperature control. Use of currently available remote transmitting technologies (suitable for the temperatures involved) and even use of P.L.C.'s (Programmable Logic Controllers) and remote P.C. (Personal Computer/Laptops) to assist in more sophisticated control schemes are possible and available. These may go a long way in reducing manpower requirements in the space during heat treatments, but entail higher initial costs. These often, one-time expenses bring high returns on investment (ROI) in labor/time saving and accuracy of control. Some special control schemes may require mounting or even embedding temperature sensing/transmitting devices in equipment, structures (beams/wall cavities) to achieve the highest potential insect destruction levels.

There are several common methods of temperature control:

1. On-Off operation of the fan (only)
2. Modulation of the air flow through Variable Frequency Drive (VFD) or VVC (Variable Volume Control) or Outlet Damper Modulation
3. On-Off Operation of the Steam Supply
4. Steam Pressure Modulation
5. Combinations of the above

**Method #1) On-Off operation of the fan (only)**, is commonly used with unit heaters for comfort heating applications. In the case of Steam Heat Treatment, this will not work very well once the terminal temperature is reached. Cutting off air flow through on/off fan operation will stop air mixing action. When this happens, areas of the room that lose heat more quickly to the outside may not achieve terminal temperature targets even while room thermostats sense a proper temperature.

**Method #2) Modulation of air discharge VFD/VVC or Outlet Damper Modulation.** This is a more expensive option, but adaptable to portable or fixed heater designs. This option adds an additional dimension to the mixing of the air and increasing agitation of the heated and cool air. Helps reduce and control stratification.

**Method #3) On-Off Operation of the Steam Supply.** This will accomplish the desired temperature control (with wider temperatures swing fluctuations!), but is not the best operating environment for the heating equipment itself. This method can result in water hammer, and increase the likelihood of leakage at joints/fittings and damage to the heating equipment. If condensate is not drained by gravity to a receiver, but is sent directly overhead, then this method is not recommended. Proper check valve selection and piping considerations are critical for this approach.

**Method #4) Steam Pressure Modulation.** This is the most preferred method of temperature control for steam heating scenarios. With this method, the steam is regulated by variably reducing the delivered steam pressure to the heater(s). The reduced steam temperature results in a lower air temperature rise but with a constant air flow/movement resulting in more uniform air mixing and temperature combinations. Additional considerations for elevated return of condensate, condensate system back pressures, and choices of draining (wasting), returning/pumping condensate must be evaluated. Use of proper piping design is imperative.

**Method #5) Combinations of All Methods.** In reality, a blended combination of all the 4) (four) main methods of control will be the result of the size and complexity of the application and available budget considerations. Many of the options may be adaptable later to systems if the consideration for future upgrades/modifications are well planned out in the initial design phase.

## Humidity Control

Sifters, old floor and bin designs and other wooden equipment/structures in food industry facilities are subject to damage from extremely low humidity. When reviewing the psychometrics of raising ambient (75-80°F), relatively dry (25-35% RH) air to temperatures between 125°F-140°F (and higher) results in desert-like Relative Humidity (RH) percentages (possibly 10% or lower!). Normally, adding any form of humidity control in the way of moist vapor to the space is not desirable, especially in dry product operations, milling, grinding, flours, etc.

There are several ways to add some moisture to the space during the steam heat treatment. These options should be developed in concert with the Pest Management Professional involved with the facility as to any detrimental affects additions of moisture during the heat treatment process may have on target insect groups. As extremely dry environments increase the likelihood of high destruction of the insect population, humidification options during heat treatment should only be considered when structural issues or potential high increases in ESD (electrostatic discharge) potential is of concern.

1. Uncontrolled Humidity release through flash/steam at condensate receivers/drains. Hot condensate (above 212°F) will have a portion of the liquid flash into vapor form when exposed to atmospheric conditions. This flashing vapor when released to atmosphere from an open/vented receiver or drain will act as a form of humidity to the space. Water vapor (in very small volumes) will dissipate quickly throughout a very low (dry) under humidified space to the areas of highest need. This form is uncontrolled and unregulated and should be utilized with caution.
2. A second method is to install a steam humidifier to direct live steam (already being sent to the steam heating equipment) into the heated discharging air from the steam unit heater. The amount of humidity (in vapor not droplet form) can be easily controlled with a properly installed humidistat.

Note that any moisture added to the space may only be desirous at / near terminal (target) temperature points, and should never be added in the process of reducing temperatures in the space back to normal / ambient conditions. Thermostats capable of operating in the higher temperature environments should only be utilized and a high limit humidistat should be considered to ensure excess humidity sensing will immediately shut down the humidifying source.

Consult with the Steam Unit Heater manufacturer/supplier for coordinated installation of any humidity control equipment.

## Construction Considerations

The use of an ***Industrial / Heavy Duty Grade Steam Heater equipment suitable for the High Temperature and potentially Higher Steam Pressure environments of Steam Heat Treatment is imperative.***

Use of ***lighter duty, commercial grade components is not recommended.*** These designs, utilizing light duty fins (easily bent, easily clogged with dust/dirt, and difficult to clean and repair), light duty tubes (often thin wall and with soldered connections not readily suitable for tougher duty service and ease of maintenance), and lower quality motors, fan components, may lead to premature failure of equipment and performance related issues, far exceeding the initial cost of equipment.

### Suggested (minimum) equipment specifications:

**Fins:** 0.016 – 0.024" Thick Aluminum or Copper Fin Embedded into Tube Materials (keyfin)

Ensure that the fins can withstand cleaning by high pressure air or wash down without bending.

**Fin Spacing:** Wide as possible to reduce clogging. Selection based on Heat Output desired.

**Tubes:** Minimum Sch 40 (Pipe) or 12 Ga (Tube) Carbon Steel or S.S. sized for the desired pressure/flow conditions.

**Headers:** Same Material and Wall or Greater than Tube Materials (mono-metallic).

**Joints:** Welded in Accordance with ASME Sect VIII or Equal (not stamped).

**Casings:** Minimum 14 Ga. Galv. Steel or S.S. as required to meet local codes or conditions

**Fans:** Aluminum, Fixed Pitch. **Fan Guards:** OSHA approved.

**Motors:** TEFC with Standard Frames/Shfts, and Insulation as required for conditions.

Options for Explosion Proof, etc. as required.

## Correct Equipment and Operating Choices

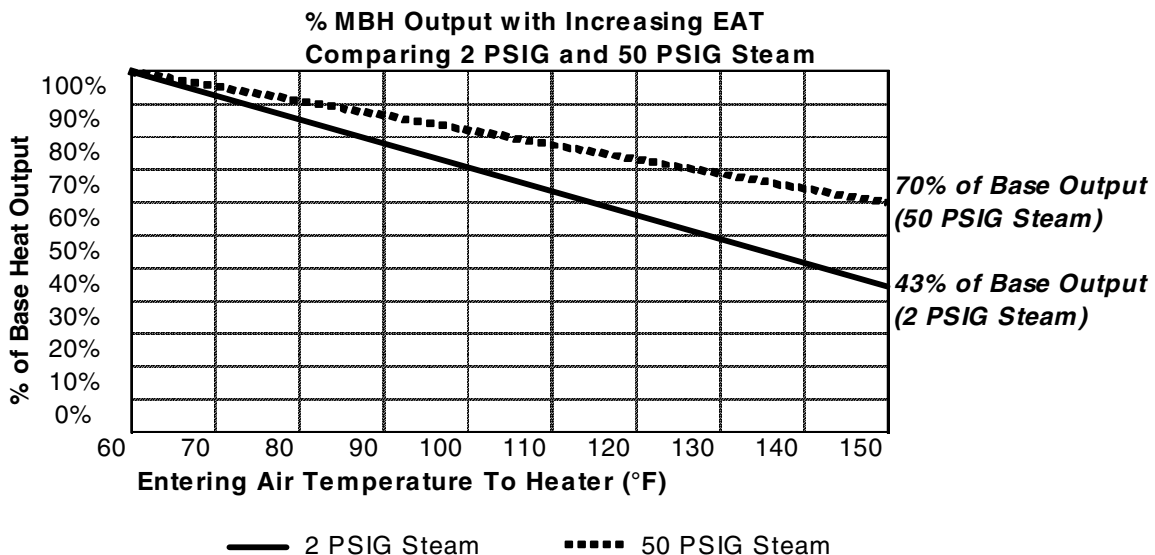
This subject is probably the least understood aspect of heat treatment. The discussion to follow will present specific arguments for the proper selection of equipment and operating conditions.

### Use Higher Pressure Steam If Possible

Higher Pressure (with higher saturation temperature and total BTU content) steam allows for the use of less expensive equipment. The steam heater finned tube heating element can be smaller due to the greater rate of heat transfer attainable from higher temperature steam.

**BTU output from the steam heater decreases with increased room temperature.** A basic fundamental of heat transfer dictates that *as the difference in temperature (TD) between the steam and the air decreases, so too does the amount of heat transferable.*

Figure 1, is a graph depicting the percent of base BTU output vs. rising ambient entering air temperature to the steam heater for identical units using 2 PSIG (219°F) and 50 PSIG (298°F) steam. Base output in MBH (1000 BTU / Hour) is the energy output at 60°F entering the steam heaters coil surface.



**FIGURE 1**

The greatest heat loss to the outside takes place at the terminal room temperature. When the entering air temperature reaches the terminal room temperature of 140°F, Figure 1 shows that the heat output of the unit utilizing 2 PSIG steam drops to 43% of the rated base output. At the same temperature (140°F) the 50 PSIG unit maintains 70% of its rated base output. This data indicates that we would need approximately twice the equipment capacity using 2 PSIG steam to accomplish the same heating as that using 50 PSIG steam.

The normal argument for using lower pressure steam in heating equipment is based on long term usage. This is based on the heat content value of the steam at lower pressure having more Latent Heat of Vaporization available for heating. In the case of the short term (36-48 hours) Steam Heat Treatment for Insect Control the same economics do not exist.

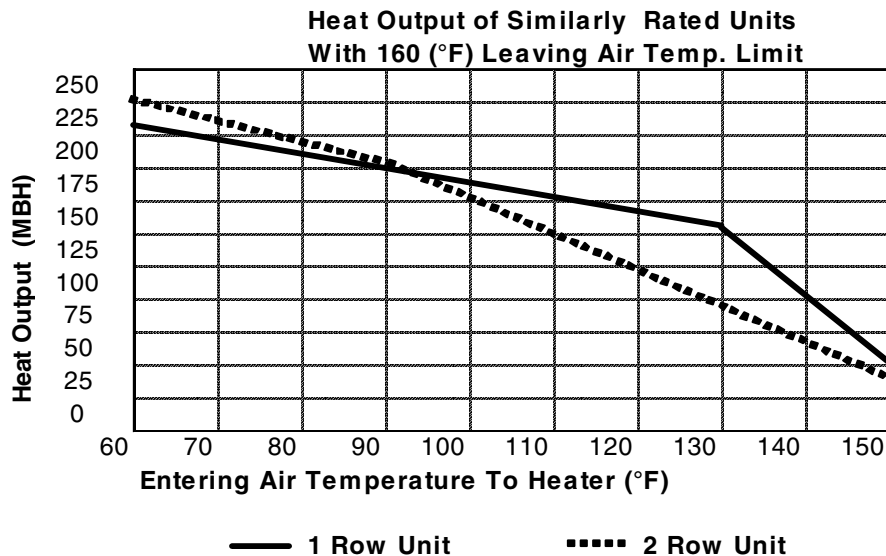
***Use higher air flow, lower air outlet temperature rise equipment (Cool Flow concept)***

There are three (3) arguments that lead to this conclusion.

1. **A lower air temperature rise means that the air from the heater is cooler and less buoyant in the surrounding air.** As such it will stay at the floor level much longer. The term used to describe this is Throw. Throw defines the effective reach of the air discharged from the unit. Throws can be increased by utilizing Hi Velocity Discharge Nozzles. However, this gain decreases air stream width.
2. **Maximum Leaving Air Temperature Issues.** As stated earlier, the terminal room temperature must be attained, but we must also limit the maximum temperatures of the room and equipment. To do this, we must limit the leaving air temperatures of the steam heaters. A common upper limit is 160°F (based on a maximum 140°F terminal space temperature requirement). This is high enough to maintain temperature, but low enough to protect most equipment from damage.

Relative to the second (2) argument, typical multi-row (2 or more) units must, necessarily, discharge air at high temperature to maintain their rated heat output. But, if we limit the leaving air temperature the multi-row steam heater cannot do this as the entering air temperature rises.

Figure 2 (below) illustrates the effect of temperature limitations on heat output.



**FIGURE 2**

Without the temperature limitation, the two lines would remain parallel at all ranges of entering air temperatures. With the limitations, however, we see that **the two row unit requires that the steam medium must be modulated at any entering air temperature (EAT) above 90 degrees.** The one row unit can maintain output up to 130°F. EAT without modulation. Further, at 140°F EAT (assumed terminal temperature point in the space), the one row unit's output is double that of the two row unit. This is true, even though the two row unit started out with the about the same output at 60°F design EAT conditions.

***Note: Subsequent discussions in this paper will assume a temperature limitation of 160°F.***

3. **The combination of lower leaving air temperatures and higher air output provide the same BTU output while covering a wider floor area.** Heat soaking of the floor area and associated equipment is what thermal heat treatment is all about!

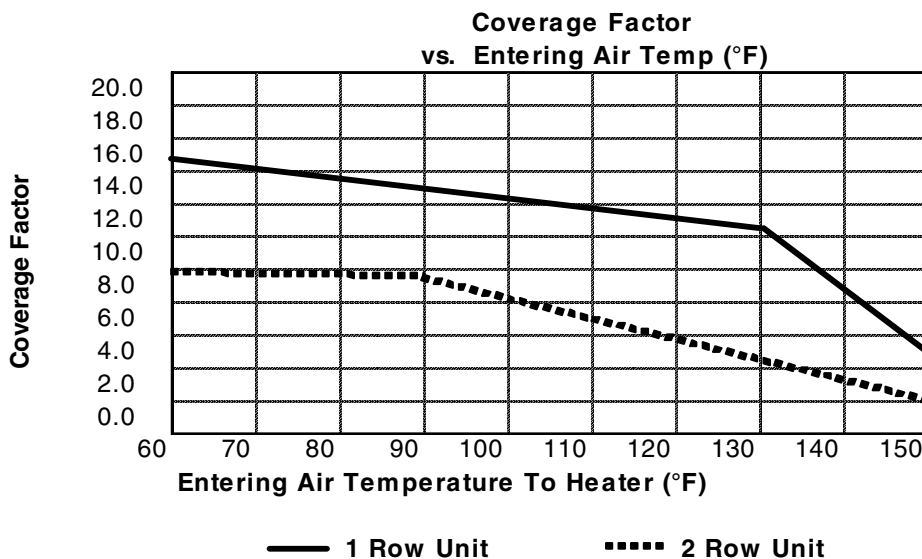


**An argument can be put forth that higher temperature air hitting the floor and equipment makes the temperature rise faster. The fact is, less floor area, low points and equipment will be reached by this air, resulting in cold spots.**

To illustrate this difference, we present a term called **coverage**. The formula for coverage is shown below:

$$\text{Coverage (C)} = (\text{CFM} \times \text{Throw} \times \text{Temperature Rise}) / 1,000,000$$

Simply Stated: **Coverage is a measure of how much air is spread over what distance and at what temperature.** The graph of **Figure 3** (below) compares the coverage of 1 Row and 2 Row Steam Heaters of the same BTU output rating.



**FIGURE 3**

The **1 Row Steam Heater** puts out higher CFM with a greater throw, but at a lower temperature than the **2 Row Steam Heater**. Note that the lower outlet temperature is still in a beneficial range related to heat transfer and temperature control of the Heat Treatment space. It is obvious that the effect of the higher CFM and throw outweigh any advantage of higher air temperature. ***Even at terminal temperature the 1 Row Steam heater has double the coverage.***

## General Guidelines for Care and Maintenance of the Steam Heating Units

All too often the best quality heating units are installed and maintained improperly, resulting in less than satisfactory performance and life. The follow are general guidelines for installation and maintenance of steam heating units. Reference to the manufacturer's Installation, Operation and Maintenance manuals is recommended for more detailed information.

1. Use Only Float and Thermostatic or Inverted Bucket Type Steam Traps for draining of steam heated equipment. All other types operate by backing up condensate between discharge cycles. Backup of condensate into heat exchangers is not recommended. This may lead to oxygen pitting, acidic corrosion and shorten the life and performance of the heat exchanger elements. If an Inverted Bucket Trap is used, it should have a Large Bucket Vent (LV) or be supplemented by a separate air vent. Utilize integrated Trap, Strainer, Valving combinations in single piping configurations to reduce space requirements and potential leak points (Trap Valve Stations – TVS).
2. Always install a vacuum breaker downstream of the unit, but before the steam trap to ensure adequate drainage during shutdown or under modulating conditions.
3. Provide a means to completely drain the unit during shutdown periods. The best way is to install an automatic temperature sensing valve that opens and drains (to gravity, floor drain, vented lower receiver) at around 100°F. This valve (CSDV) will stay open at all times during shutdown. Remember, these units will be shut down most of the time and if steam is left on upstream of the inlet isolation valve, often the steam valve might leak by,



which is not uncommon. Isolating the steam and disconnecting steam from portable steam heating units is standard procedure, but insure that all condensate is drained completely before storage.

4. If condensate must be lifted or if the condensate return system is pressurized, install a check valve downstream of the steam trap.
5. Make sure motors are rated for the operation at the maximum expected ambient conditions.
6. Insure fins on steam coil surfaces are spaced as wide as practical to facilitate easy cleaning and reduce potential dust/dirt collection points on the service.
7. If wet wash down is required ensure all design and components meet requirements for cleanup and drain out to avoid leftover moisture collection points in the units.

## Cost Concerns

The Cost of Steam Heat Treatment as part of an Integrated Pest Management program can vary widely from plant to plant. Some of the variables affecting cost are:

1. The amount of outside wall space of the facility and/or building segment to be heat treated.
2. The climate (Latitude) of the plant location and overall climactic conditions, including prevailing winds relative to the structure.
3. The ceiling heights of the facility and whether treatment will be on single floor, multi-floor or open mezzanine type of facilities.
4. The amount and type of insulation in walls and ceilings and general building envelope construction.
5. The amount and type of glass area.
6. The amount, type and materials of construction of equipment located in the space to be heated. Relative positioning of the equipment as relates to practical air movement requirements.
7. Steam Availability relative to the site to have heat treatment applied. In place, nearby, remote, or currently unavailable (requiring a rental steam source), will affect the cost. Engineering assistance from a full service steam knowledgeable provider is critical if in-house steam engineering is not currently available.
8. Condensate Return/Flash Recovery. Is the plant currently returning condensate, will it be wasted, or is their alternative usage for the hot condensate?
9. Electrical access, current and required? Recommend higher Voltage/Phase where possible to reduce wire gauge sizes. Ensure consideration for safety issues related to local codes and any explosive/hazardous area concerns are addressed.
10. The availability of wall and floor space to mount the units.

Items 1 through 6 pertain to the heat loss through the walls and ceilings of the space to be heated. Items 7-9 pertain to the utilities infrastructure (steam/condensate/electrical) to be considered. Item 10 pertains to layout for fixed and portable units to be considered.

Before any equipment can be sized, a thorough audit and engineering analysis by a fully qualified steam/energy engineering group along with input from the current Integrated Pest Management contractor should be conducted. Strong consideration for in-depth evaluation of all items shown should be part of any initial and/or engineering audit and will be well worth the initial cost to avoid extremely expensive errors or omissions later on.

**One installation developed for a large space at a facility with dimensions 90 ft. x 65 ft. with 18 ft. high ceilings (approx. 105,300 cu. ft.) with one (1) outside wall and a fair amount of open space had general steam related equipment costs and auxiliaries estimated at \$25,500.00. This cost included the heating units along with loose steam traps, control valves and all other hardware exclusive of installation and condensate piping.**

The equipment list included:

8 (eight) 1 Row Steam Unit Heaters (For Fixed Installations) @ 156,000 BTUH rating at 2 PSIG Steam.  
1 (one) 1 Row Steam Unit Heater (For Portable Spot Usage) @ 156,000 BTUH rating at 2 PSIG Steam.  
NOTE: Rating shown were at 60°F Ent. Air Temp. and 2 PSIG Steam at the Heater Inlet. Actual steam pressure used was 50 PSIG at the Units. This resulted in actual unit rating at 234,000 BTUH per Unit.  
(156,000 BTUH x 8 Units = 1,248,000 BTUH Total Available (@ 2 PSIG)  
(234,000 BTUH x 8 Units = 1,872,000 BTUH Total Available (@ 50 PSIG)

## Summary

Use of Steam and Steam Heating Equipment as a viable support to an Integrated Pest Management Program for any food facility interested in destruction of insect pests is well proven. The areas of equipment design, control, and modifications to reduce required heat up times and adapt to various plant scenarios is constantly evolving. The ultimate challenge is to reduce necessary manpower, reduce plant downtimes, and insure that equipment design, selection, application and operation fully satisfies the demands of current and future needs in this key quality assurance and sanitation function.

Working with the most knowledgeable and experienced companies in the steam/energy service and equipment manufacturing areas will insure targeted goals are achieved.



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