CO-RAY-VAC®

Custom-Engineered, Low-Intensity Infrared Heating Systems

Design Manual

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127500US Rev. A

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1. Concept

The concept of Co-Ray-Vac is easy to understand. However, it means discarding old ideas because Co-Ray-Vac is a different kind of heating system. The things that make it different also make it better.

Co-Ray-Vac is a gas-fired, vacuum-operated, low-intensity infrared heating system incorporating a patented incremental burner system.

Gas-Fired means it uses clean-burning Natural or LP gas.

Vacuum-Operated means that the vacuum pump draws all the products of combustion through the system and completely expels them safely outdoors.

Low-Intensity means the radiant surfaces of the heat exchanger tubes do not glow red; instead they operate at a lower temperature (less than 900°F) and radiate heat at lower intensity per square foot of radiating surface. Area coverage is provided by long runs of 4" O.D. steel tubing which hang from the ceiling or roof supports. Aluminum reflectors direct the radiant heat downward to occupied areas.

Radiant refers to the heat radiated by the Co-Ray-Vac system. Because this heat is in the form of infrared rays, it does not directly heat the air. Instead, the rays heat objects such as the floor, cars, machines and people. The warm objects in turn heat the air.

Incremental Burner System means that several burners can operate in series and fire into the same run of tubular steel heat exchanger that carries the combustion gases from upstream burners. Each of these burners in a radiant branch may have different firing rates; also, the space between burners may vary. This allows the designer to match heat gain to heat loss for each area of the building. Firing burners in series provides higher thermal and radiant efficiency and this is one of the patented features of Co-Ray-Vac.

In a properly designed low-intensity radiant system, the occupants should be barely aware of the radiant heat when the system is firing. They will feel little or no change when the thermostat is satisfied and the system is not firing. This combines with warm floors and draft-free operation to improve the mean radiant temperature of the space. This is the key to the exceptional comfort and fuel efficiency provided by the Co-Ray-Vac system.

2. The Co-Ray-Vac System

Each Co-Ray-Vac installation consists of one or more vacuum pump systems. Each these consists of one vacuum pump, a control system, and a number of burner module It also includes an extended heat exchanger surface in the form of 4" steel tubing co ered by high efficiency aluminum reflectors to reflect the radiant heat downward to th floor. The tubing nearest the burners radiates with the most intensity and is called **radiai pipe**. This should be located over areas with the greatest heat loss. The rest of the tubir surface radiates with less intensity and is called **tailpipe**. This can be located in area with lower heat loss.

While it is important to locate radiant tubes and tailpipe over areas with high heat los such as the perimeter of the building, it is not always essential to cover all areas directl with radiant heat. Center areas and other areas of low heat loss can be adequately hea ed without direct coverage if the input of the system is adequate for the total building However, to achieve the highest degree of comfort and fuel savings, it is recommende that the Co-Ray-Vac system be located to provide as complete and even a distribution a is practical. In addition, several different reflector and shield configurations are availabl to direct the radiant heat to and away from desired areas.

Figure 1 illustrates the components of a typical Co-Ray-Vac system.

a. Safety

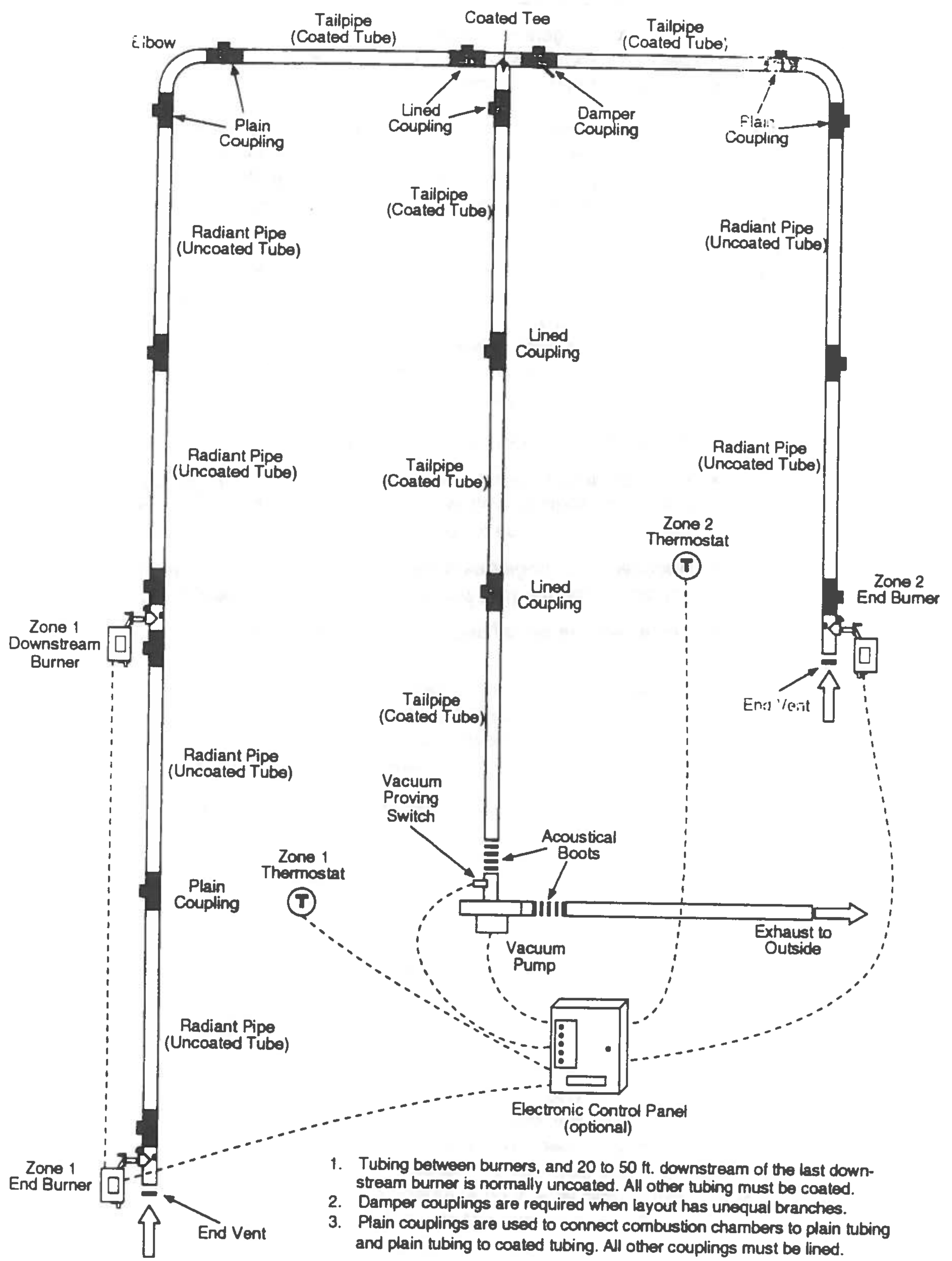
Safety is a prime consideration of Co-Ray-Vac. First, there is a pre-purge of the complete tube network prior to flame ignition. Then, to ensure that there will be no gas flow unless the vacuum pump is operating, there are two valves in series in each burner that must be energized, as well as a zero regulator. Depending on pump configuration, there will also be either a vacuum proving switch or a centrifugal motor interlock that must activate prior to ignition. Additionally, slow opening gas valves provide smooth ignition and enhance reliability.

With Co-Ray-Vac, all equipment and controls are A.G.A. Laboratory design certified, both as individual parts and also as a complete heating system. Also, individual electrical component parts are UL listed as applicable.

b. Zero Regulator

Co-Ray-Vac uses a 100% pre-mix burner with the input dependent on system vacuum. It is the only true vacuum operated system available today in that *both* air and gas are pulled into the burner head by system negative pressure. With no vacuum, the zero regulator prevents gas flow. When vacuum is present, the burner fires and input increases as vacuum increases. As the input increases, the amount of air also increases. Over the normal range of operating vacuum, the gas/air ratio is essentially linear.

This unique and patented feature provides optimum combustion conditions at all times and is unaffected by fluctuations in fuel pressure, dirty air filters, changes in atmospheric pressure, wind velocity or other climate conditions.



1. Tubing between burners, and 20 to 50 ft. downstream of the last downstream burner is normally uncoated. All other tubing must be coated.
2. Damper couplings are required when layout has unequal branches.
3. Plain couplings are used to connect combustion chambers to plain tubing and plain tubing to coated tubing. All other couplings must be lined.

Figure 1: Illustrative View of Co-Ray-Vac Installation

c. Fuel Savings and Comfort

The heating industry generally agrees that space heating can be accomplished with l input capacity when a radiant heating system is utilized, rather than with a conventic convective heating system. Why is this so?

A conventional, convective heating system, such as a unit heater or central furn works by heating the air, which then indirectly heats the area. Infrared energy from a Ray-Vac heats objects, people and surfaces, not the air. The warm objects and floor ate a heat reservoir, which then reradiates to the surroundings and also heats the ai convection.

The radiant energy received by the occupants, directly from the heater or indirectly fi the heater via reradiation, serves to increase the mean radiant temperature (MRT) of occupant. In a manner similar to direct sunlight, the increased MRT allows the occup to perceive a comfort condition at a much reduced air temperature (sometimes as m as 7-10°F lower). The resulting reduced air temperature within the space provides the lowing fuel-saving advantages:

- Reduced stratification of air within the space;
- Reduced actual transmission heat loss due to lower temperature inside than assumed design condition, as well as substantially lower ceiling and upper sid wall temperature due to reduced stratification (25-30°F lower is not unusual);
- Reduced air change heat loss, to the extent that exfiltration through cracks or openings near the roof will be decreased due to decreased stack effect;
- Decreases the actual degree days experienced.

3. Building Heat Loss and Sizing the System

The building heat loss must be calculated in strict accordance with the current ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) Guide. The Co-Ray-Vac system input is determined in concert with the required radiant adjustment to heat loss and height adjustment factors.

a. Radiant Adjustment to Heat Loss

The practice of applying an adjustment factor to heat loss calculations for radiant heating systems is well known within the radiant heating industry, having been used by manufacturers for over 25 years. Recently, a number of studies have been conducted to identify the values of the adjustment factor in the range of 0.8 to 0.85 depending on efficiency (higher efficiency uses lower factor). This adjustment can be more thoroughly understood when considering the following radiant effect issues:

- Infrared energy heats objects, not the air;
- Lower ambient temperatures reduce the amount of air infiltration;
- Less air stratification with radiant heat;
- Lower ambient air temperatures reduce the transmission heat loss across walls and roof;
- Elevated floor temperature provides a thermal reserve capacity;
- Increase mean radiant temperature allows occupants to perceive thermal comfort at the reduced air temperature.

Each of these issues impacts favorably on the utilization of the installed capacity of the radiant heating system. This fact, together with the realization that the standard ASHRAE heat loss calculation methods (particularly the transmission heat loss coefficients) have been developed specifically for conventional hot air systems, demonstrates the need for the heat loss adjustment factor.

In general, an adjustment factor of 0.8 should be used for-Co-Ray-Vac systems.

However, an adjustment factor of 0.85 should be used for Co-Ray-Vac systems designed with less than 2.0 ft./flow unit of tailpipe (non-condensing mode). See section 6 for details concerning flow loading calculations.

b. Radiant Height Adjustment Factor

As discussed above, the installed capacity of radiant heating systems is typically reduced as compared to the calculated heat loss due to the radiant effects associated with a properly designed radiant heating system. The ability of a radiant system to provide the advantages of these radiant effects rests largely with the ability of this system to establish a reserve heat capacity in the floor. Without this reserve capacity, radiant comfort cannot be achieved. (The exception is in station heating/spot heating applications where sufficiently high levels of direct radiation are received from the heater.) The height adjustment factor is a means to insure adequate floor level radiant intensity to "charge" the floor heat reservoir. Figures 2 and 3 illustrate the relationship of floor level intensity to height for single and multiple (overlapping) Co-Ray-Vac burner runs.

Additionally, higher mounting heights for radiant heating appliances increase the probability for direct radiant energy loss due to exposure of longer wall surfaces.

Proportionately larger wall surfaces also remove energy from the floor to a larger degree decreasing the heat reservoir.

The increased input capacity recommended by a height adjustment factor is not extrane ous as compared to the heat loss calculation. Rather, it is a realization that in order tc maintain radiant comfort conditions (and the economic benefits) a minimum radiant leve must be maintained at the floor.

It is recommended that an adjustment to the heat loss of 1% per foot for mountin(heights above 20 feet, be added up to 50-60ft.. Above this height, additional correctio overstates the BTU requirement as determined by the heat loss.

Example 1

Given a building with a calculated heat loss of 350,000, what is the installed capacity required of a Co-Ray-Vac system mounted at 30 ft.?

Installed Capacity = Heat Loss x Radiant Adjustment x Height Adjustment

For Co-Ray-Vac systems, a 0.80 radiant adjustment factor is used.
The height adjustment is 1% per foot over 20 feet, or 1.10.

$\therefore$ Installed Capacity = 350,000 BTU/Hr x 0.80 x 1.10 = **308,000 BTU/Hr.**

Example 2

Given a building with a calculated heat loss of 500,000, what is the installed capacity required of a Co-Ray-Vac system mounted at 60 ft.?

Installed Capacity = Heat Loss x Radiant Adjustment x Height Adjustment

For Co-Ray-Vac systems, a 0.80 radiant adjustment factor is used.
The height adjustment is 1% per foot over 20 feet, or 1.40.

$\therefore$ Installed Capacity = 500,000 BTU/Hr x 0.80 x 1.40 = **560,000 BTU/Hr.**

Note in example 2, if equipment had been conventionally sized based on thermal out only, a nearly identical input requirement would result. **For mounting heights above 60ft., no further correction is generally necessary if the floor level radiant inten: is sufficient to establish a reserve capacity (hence radiant comfort), and the h loss requirement is satisfied based on thermal output.**

Due to the complexity of installations with mounting heights over 50-60 ft., it is advis: to contact the factory for further information regarding the specific application.

c. Selecting the Burners

The number of burners and firing rate for each must be specified in the design layou addition, an end vent plate must be provided for each end burner to match its firing The following factors should be considered when selecting burner rate:

- Flow loading restrictions
- Length of radiant branches
- Distance required between burners
- Desired radiation intensity.

In general, lower burner rates can be used for lower mounting heights or where lower heat gains are required. Higher burner rates are used primarily with higher mounting heights or where high heat gain is required.

The number of burners required can be calculated by dividing the input rating of the selected sizes into the calculated Co-Ray-Vac system required installed capacity.

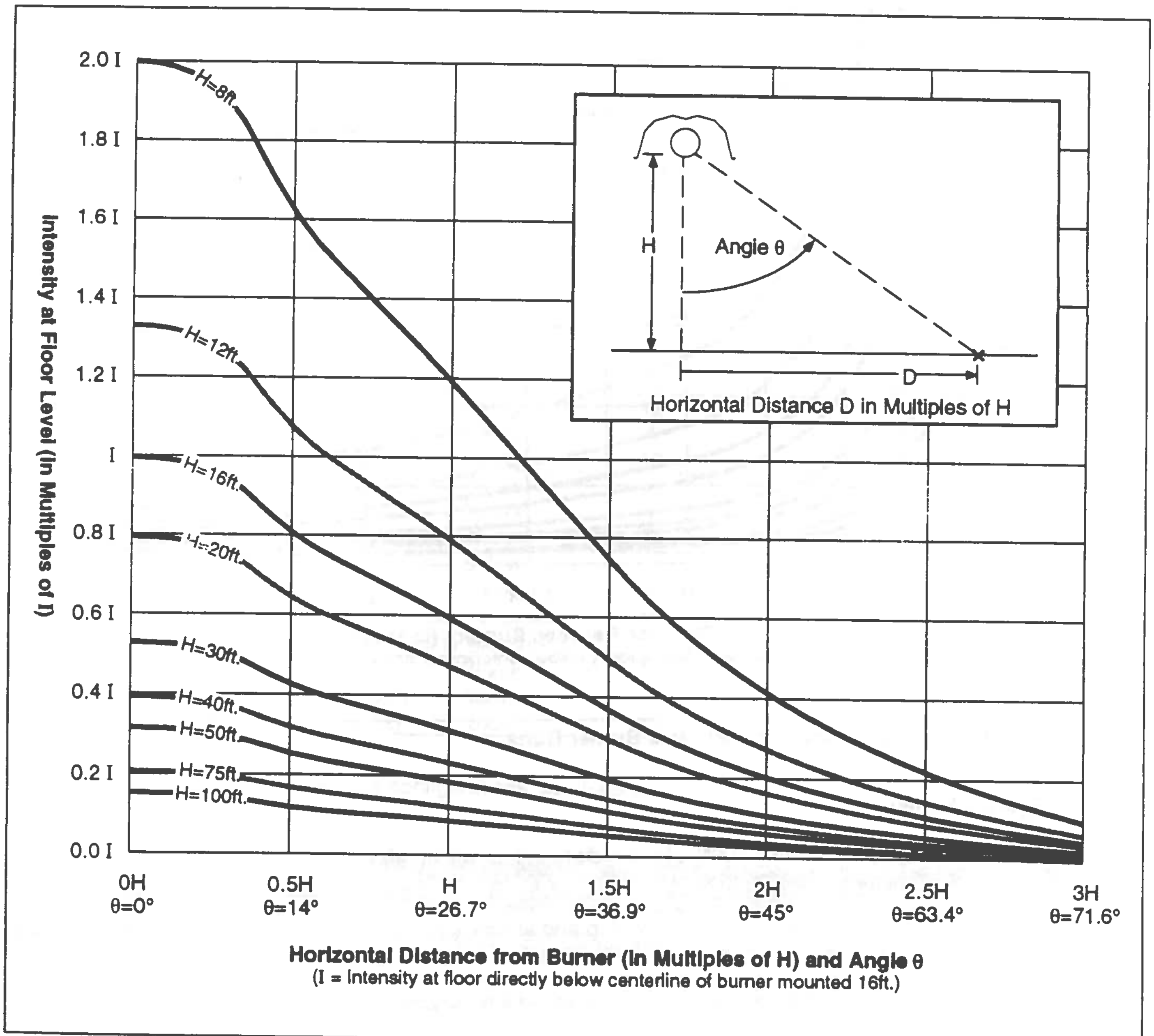


Figure 2: Burner Intensity for Single Burner Runs

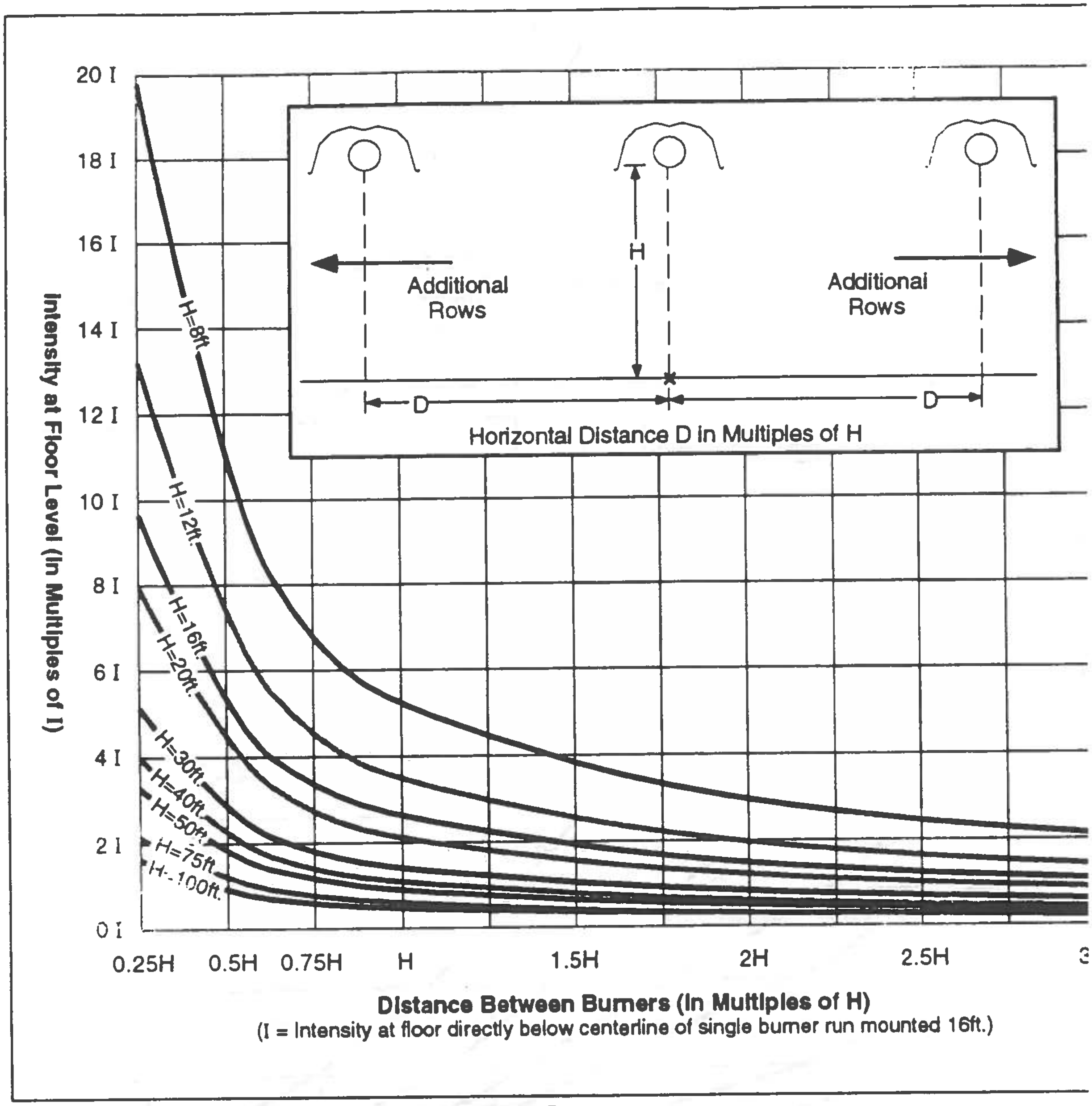


Figure 3: Burner Intensity for Multiple Burner Runs

Figure 3 Notes:

- This graph assumes 100% of the radiant output will be allocated to a floor area as defined 120° pattern width.
- The values shown include the overlap and are minimum values with at least two rows of bu on either side. The values of intensities are less between all other rows.
- With spacing of 3H between rows, the added intensity from adjacent rows is less than 5%.

4. Clearances to Combustibles

Table 1: Minimum Clearances to Combustibles
All clearances measured in inches from tube surface.

Reflector Type	Position	B-2,4,6,8	B-9	B-10,12,12A	B-12*,12A*
Standard Reflector, any location	Below	48	40	60	48
	Above	4	4	4	4
	Side	20	20	36	24
One Side Extension	Below	56	46	60	54
	Above	4	4	4	4
	Side w/ Ext.	12	12	12	12
	Side w/o Ext.	20	24	42	34
Two Side Extensions	Below	56	46	60	54
	Above	4	4	4	4
	Side	12	12	12	12
One foot wide Deco Grille	Below	48	38	56	40
	Above	4	4	4	4
	Side	12	16	18	18
Two foot wide Deco Grille	Below	48	38	56	40
	Above	4	4	4	4
	Side	12	16	18	18
Barrier Shield	Below	12	-	-	-
	Above	4	-	-	-
	Side	12	-	-	-
Universal Shield (position 1)	Below	12	-	24	-
	Above	4	-	8	-
	Side	12	-	18	-
Universal Shield (position 2)	Below	48	-	48	-
	Above	4	-	4	-
	Side	24	-	36	-
Universal Shield (position 3)	Below	56	-	60	-
	Above	4	-	8	-
	Side w/ Shield	12	-	12	-
	Side w/o Shield	30	-	42	-
Standard Reflector, downstream	Below	18	-	24	-
(20 ft downstream for CRV 2,4,6,8)	Above	4	-	4	-
(30 ft. downstream for CRV 10,12)	Side	10	-	18	-

* For End Burner position only

For a schematic view of reflector configurations, see Figure 4.

⚠ WARNING ⚠

FIRE OR EXPLOSION HAZARD

In all situations clearances to combustibles must be maintained. Failure to observe clearances to combustibles may result in property damage, severe injury, or death.

Minimum clearances must be maintained from vehicles parked below the heater. Signs should be posted in storage areas to specify maximum stacking height to maintain required clearances to combustibles. Caution should be used when running the system near combustible materials such as wood, paper, rubber, etc.

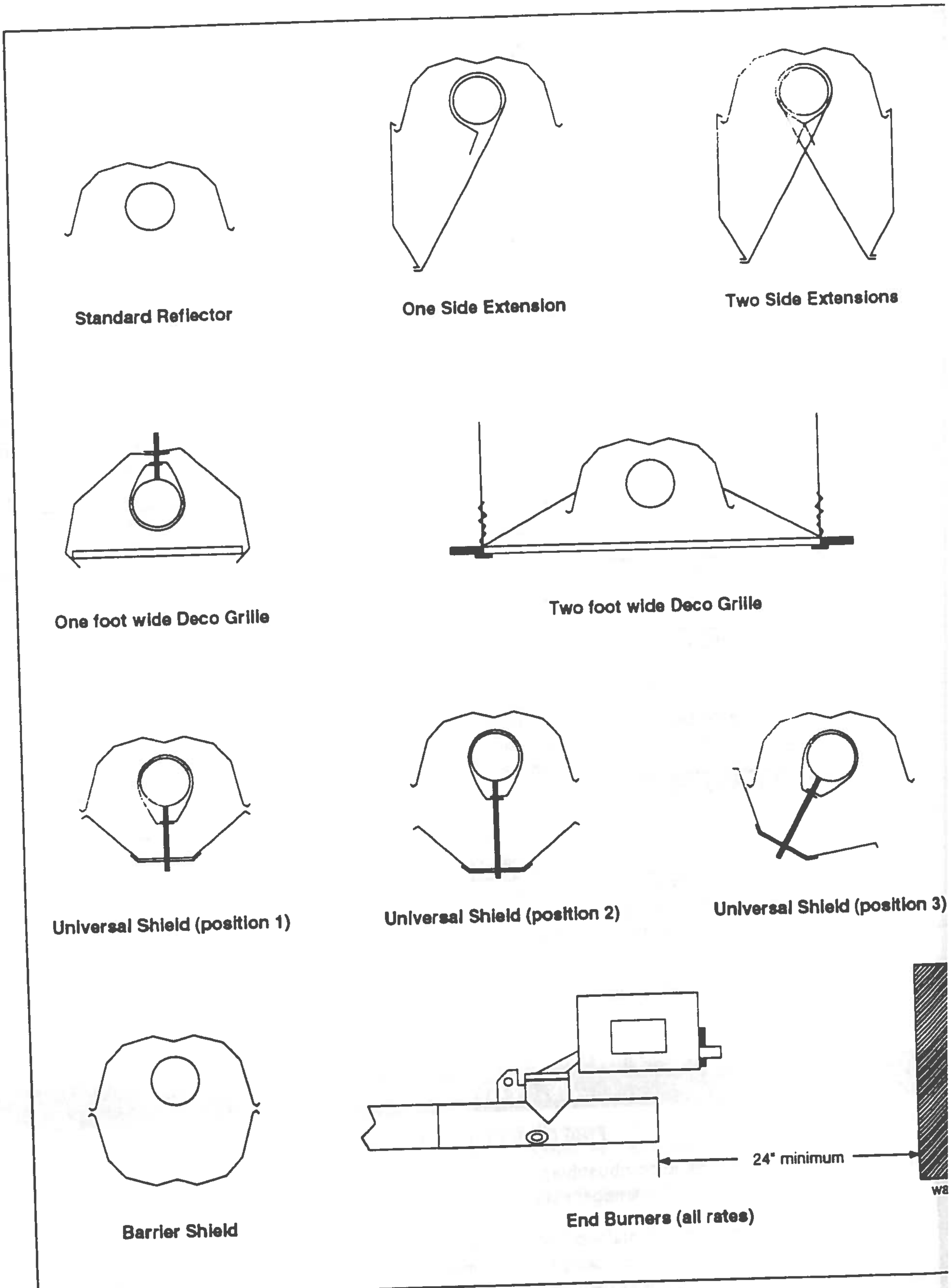


Figure 4: Reflector Configurations for Clearances to Combustibles

5. Flow Loading

The patented Co-Ray-Vac burner system allows a number of burners to be installed in series, in the same radiant tube, resulting in long, continuous radiant emitting surface to give even heat distribution within the building.

To enable the burners to be correctly located within the tube, to maintain system operating vacuum and obtain design flue gas temperatures at the vacuum pump, the design layout is based on a simplified flow principle using a "flow unit." Figure 5 details example calculations of flow units for various CRV system configurations.

The flow unit is defined as the amount of fuel/air mixture for a heat input of 10,000 BTU/Hr. This corresponds to a flow rate of 1.83 cfm at 65-70°F.

For the purpose of design, flow units are considered to enter the Co-Ray-Vac system in one of two ways:

- Through the burner.
- Through the end vent plate.

Flow units exit the system as spent products of combustion via the vacuum pump.

Table 2 lists the flow unit values associated with each burner firing rate, its associated end vent, and minimum flow unit requirement entering a combustion chamber. Table 2 also summarizes design and flow loading parameters for Co-Ray-Vac systems.

The purpose of the end vent air is to provide that part of the burner inlet flow required to dilute the hot combustion gases at the burner, thereby promoting uniform heating of the tube while avoiding excessive heating of the combustion chamber.

For the end burner, the burner inlet flow consists entirely of the end vent air. For all other burners, the burner inlet flow consists of the total of the end vent air plus the combustion gases from all upstream burners.

The requirement for minimum burner inlet flow is met if the total flow units entering the combustion chamber meets or exceeds the minimum as shown in Table 2.

a. Radiant Branch Flow

The flow in a radiant branch consists of the end vent flow units plus the flow units of combustion air from all burners.

The limiting factor for maximum flow in the radiant section has been determined experimentally in terms of the maximum burner inlet flow units that can be tolerated without degradation of combustion characteristics at the last downstream burner. Also, if more than the maximum number of burners are installed per radiant branch, the vacuum loss across the additional burners will increase appreciably.

This maximum flow in the radiant branch can be expressed for each burner firing rate by either a maximum number of burners per branch or the corresponding maximum number of flow units. Refer to Table 2.

Burner Model:	B-2	B-4	B-6	B-8	B-9*	B-10	B-12A	B-12	Mix
Fuel	both	both	both	both	both	both	Nat.	LP	-
Input (BTU/Hr x 1000)	20	40	60	80	90	100	110	120	-
Flow Units per Burner	2	4	6	8	9	10	12	12	-
Flow Units per End Vent	6	10	15	20	15	20	20	20	-
Minimum Flow Units Entering Combustion Chamber	6	10	15	20	15	20	20	20	-
Maximum Number of Burners per Branch	6	4	4	3	2	3	2	2	4
Maximum Number of Flow Units per Branch	18	26	39	44	33	50	44	44	54
Radiant Tube Length (distance between burners)									
Minimum (ft.)	10	12.5	20	25	20	30	35	35	-
Recommended (ft.)	15	20	25	30	25	40	50	50	-
Maximum (ft.)	20	25	35	45	30	60	70	70	-
Tailpipe Length per Flow Unit									
Minimum (ft.)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Recommended (ft.)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Maximum (ft.)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Minimum Distance from Burner to Downstream Elbow (ft.)	5	5	10	10	10	15	15	15	-
Minimum Distance from Burner to Upstream Elbow (ft.)	2	2	2	2	2	2	2	2	2
Suggested Minimum Mounting Height (ft.)	8	8	8	10	10	15	15	15	-

Table 2: Design Parameters

* CRV B-9 burner requires first downstream tube to be aluminized heat-treated.

Installed Altitude (ft. above sea level)	Maximum Flow Units EP-100	Maximum Flow Units EP-200
0ft - 2000ft.	66	110
2001 ft. - 3000 ft.	63	105
3001 ft. - 4000 ft.	60	100
4001 ft. - 5000 ft.	57	95
5001 ft. - 6000 ft.	54	90
6001 ft - 7000 ft.	51	84
7001 ft. - 8000 ft.	48	80
8001 ft. - 9000 ft.	45	75

Table 3: Vacuum Pump Capacity

Note: Do not use the EP-100 pump with tailpipe longer than 1.7 ft./Flow Unit.

b. Tailpipe Flow

Excessive flow loading in a single section of tailpipe can cause low vacuum and lower effective pump capacity if care is not taken to observe the necessary design requirements.

It is important to check the length of tailpipe for each radiant branch, and verify it is within ±5% of the recommended length. If the proper end vent vacuum is to be maintained, the length of tailpipe must not be excessive for the flow units being carried by that section of tailpipe. Refer to Figure 6 to determine adherence to vacuum line loss requirements.

c. Vacuum Pump Capacity

The flow unit capacity of the vacuum pump is indicated in Table 3 as a function of installed altitude. When the CRV system is designed in accordance with this set of instructions and is in proper operating condition, a vacuum from 2-3" w.c. will be obtainable at each end vent (i.e. at all burners.)

There are a number of critical design requirements which, if not met, will reduce the vacuum obtainable and thereby the effective flow capacity of the vacuum pump. These include:

- **Minimum Length of Tailpipe**—if less than the minimum length of tailpipe is provided per radiant branch, there will be insufficient cooling of the combustion gases and improper operation of the vacuum pump.
- **Line Loss Check for Tailpipe** is applicable to sections of tailpipe which are common to two or more radiant branches (i.e. shared lengths). See Figure 6.
- **Excessive back pressure** on discharge line of vacuum pump as caused by partial blockage or too much flow for length.
- **Air leaks** in the system as caused by poor installation, missing view port windows in combustion chambers, leaky burner gaskets, missing or improperly installed end vent plates, poor joints at couplings, obstruction inside the pipe, or incorrectly set dampers.
- **More than maximum number of burners** or flow units per radiant branch.
- **Excessive number of elbow or tee fittings** which increases head loss.

If the distance required for the tailpipe to reach the pump position of the system is greater than allowed, then there are some alternatives:

1. Use separate branches of reduced flow units for half the distance and then tee together for the balance of the run.
2. Use separate branches from the pump, each with less flow units. Then each branch could be longer as required.

d. Flow Unit Calculations

Key to Symbols

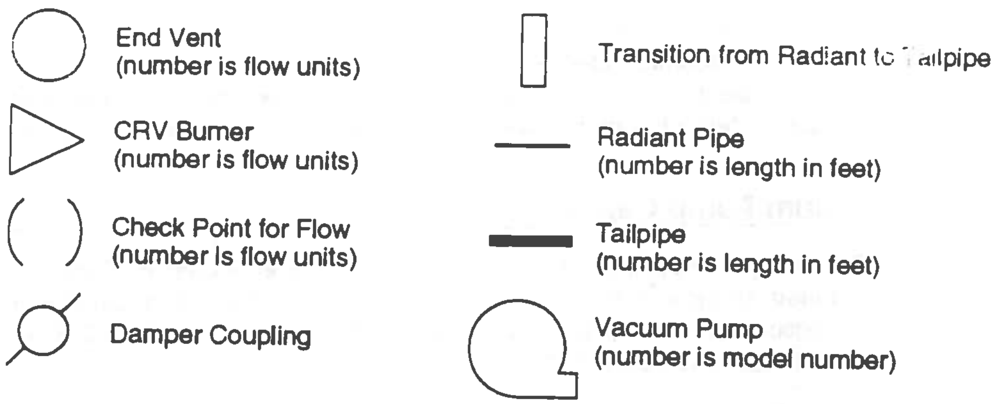
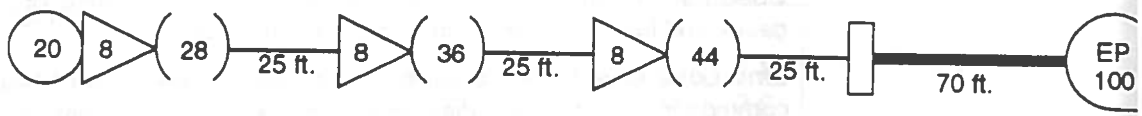
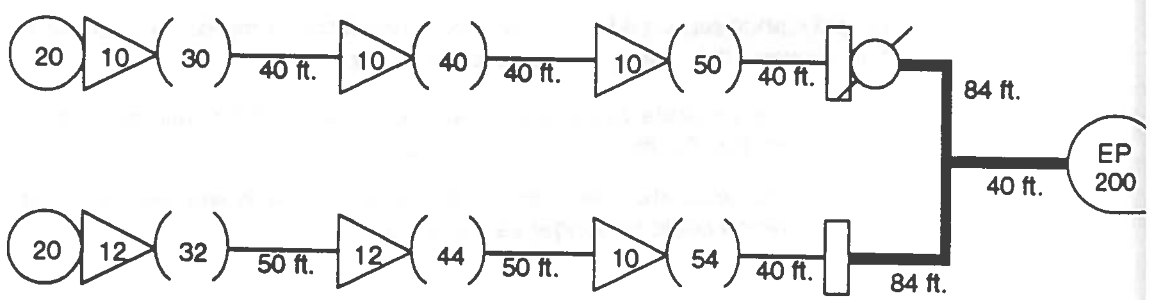


Figure 5a: CRV System with One Branch
(3 CRV B-8 Burners in series, minimum radiant pipe, no elbows, sea level)



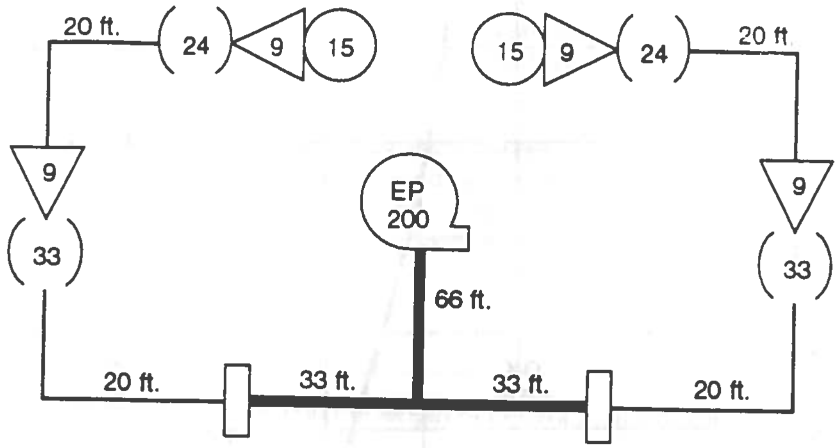
- From Table 1, minimum radiant tube length for B-8 burners is 25 ft.
- From Table 2, at sea level EP-100 vacuum pump can safely handle 44 flow units.
- Maximum tailpipe length for EP-100 pump is 1.7 ft. per flow unit (1.7 ft. x 44 flow units = 74.8 ft.). Round 74.8 ft. down to 70 ft..
- From Figure 6, 44 flow units are allowed in 70 ft. of shared tailpipe.

Figure 5b: CRV System with Two Uneven Branches
(3 CRV B-10 Burners in branch 1, 2 CRV B-12 Burners and 1 CRV B-10 Burner in branch 2, recommended radiant pipe, recommended tailpipe, 2 elbows in radiant section, sea level)



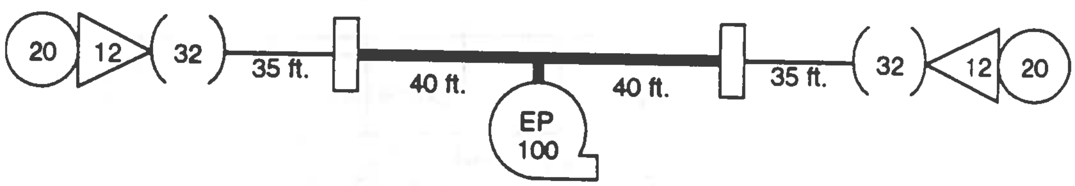
- From Table 1, minimum radiant tube length for B-10 burners is 40 ft.; for B-12 burners it is 50 ft..
- Recommended tailpipe length is 2 ft. per flow unit (2 ft. x 104 flow units = 208 ft.)
- From Table 2, at sea level EP-200 vacuum pump is required to handle 104 flow units.
- If system were to be installed above 3000 ft., this configuration would exceed the EP-200 capacit and would thus have to be redesigned.
- According to Table 1, the maximum number of flow units in a mixed branch is 54. Therefore, if branch 2 had 3 B-12 burners it would exceed the flow unit limit.
- From Figure 6, 104 flow units allowed in 40 ft. w/ 1 elbow per 50 ft. of tailpipe.

Figure 5c: CRV "SC" System with Equal Branches and Mixed Tailpipe
(2 CRV B-9 Burners in series in 2 branches, minimum radiant pipe, recommended tailpipe, 4 elbows in radiant section, 4000 ft. altitude)



- From Table 1, minimum radiant tube length for B-9 burners is 20 ft.
- To achieve CRV "SC"short clearances, the first 10 ft. section of downstream radiant tube from each B-9 burner must be aluminized.
- Recommended tailpipe length is 2 ft. per flow unit. The two individual 33 ft. sections of tailpipe each handle 16.5 flow units from their respective branches. The combined section must handle the remaining 33 flow units. Therefore, the final section must be 66 ft. long (33 flow units x 2 ft. per flow unit.)
- From Table 2, at 4000 ft the EP-100 vacuum pump can handle 60 flow units, therefore, the EP-200 must be used.

Figure 5d: CRV B-12 End Burner System
(1 CRV B-12 Burner per branch, 2 branches, minimum radiant pipe, minimum tailpipe, no elbows, sea level)



- From Table 1, minimum radiant tube length for B-12 burners is 35 ft.
- Minimum tailpipe length is 1.2 ft. per flow unit (1.2 ft. x 32 flow units = 38.4 ft.). For convenience, round this number to the nearest 10 ft. section: 38.4 ft ≈ 40 ft.
- From Table 2, at sea level EP-100 vacuum pump can safely handle 64 flow units.
- The end burner only B-12 system qualifies for the shorter clearances in column 4 of Table 3: <u>Minimum Clearances to Combustibles</u> on pg 9. If the two burners were in series in one branch, the clearances in column 3 would apply.

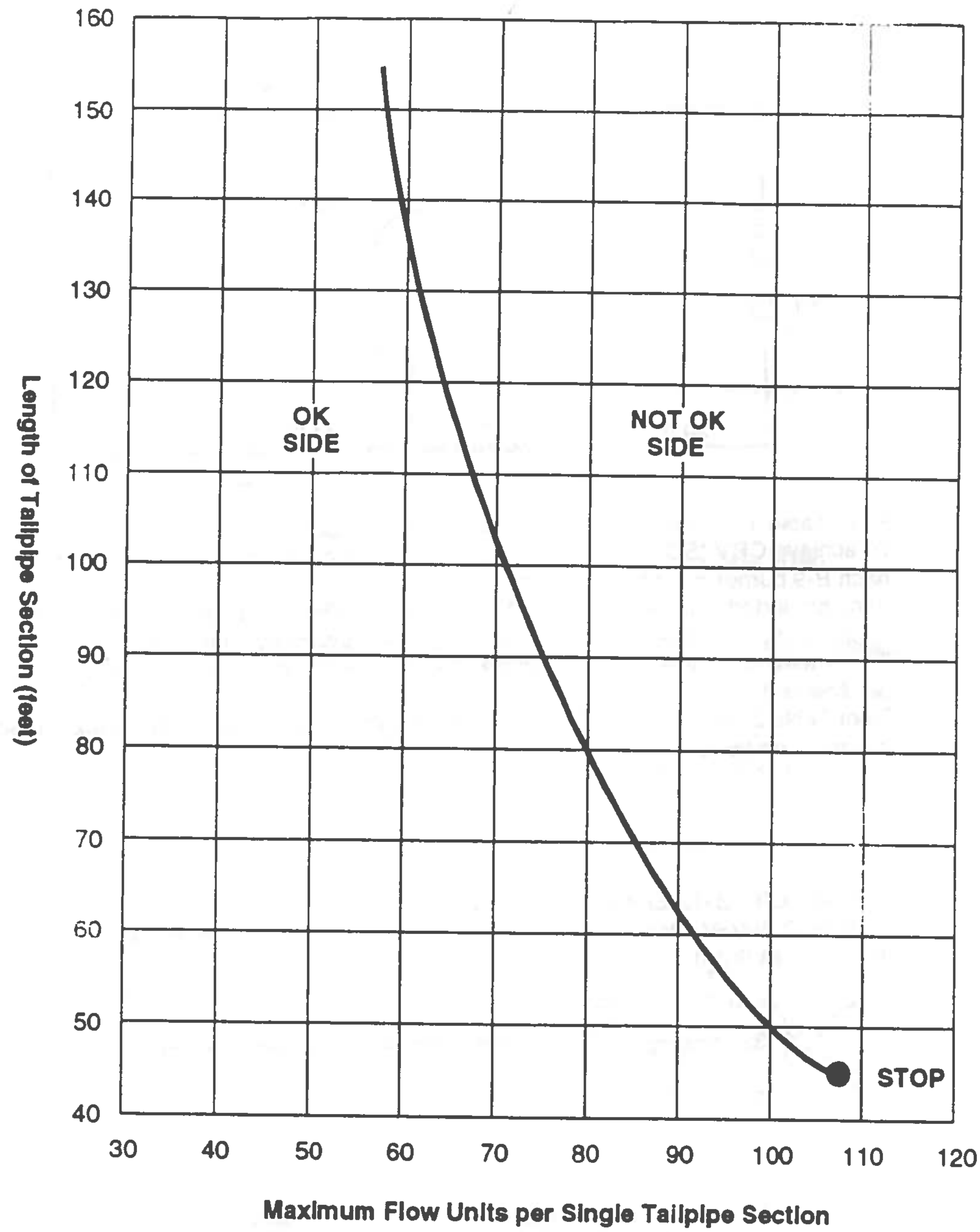


Figure 6: Vacuum Line Loss Requirements for Tailpipe

Figure 6 Notes:

- Readings for length and flow when plotted on graph must fall on OK side to avoid excess vacuum losses.
- Lengths shown include allowance for 1 elbow every 50 ft.; deduct 15% of length for each ad tional elbow used per 50 ft. length

6. Heat Exchanger Surface

The main purpose of the tailpipe and the radiant pipe is to provide sufficient heat exchanger surface to transfer the heat from the flue gases to the tube wall where it can be released from the outside surface of the tube as useful heat. Radiant pipe is defined as the tubing between burners firing in a radiant branch, plus the radiant tubing immediately following the last downstream burner. Tailpipe is defined as all tubing between the radiant pipe and the vacuum pump.

Most of the radiant heat supplied by each burner is released from the outside surface of the radiant pipe; the balance is released by the tailpipe. The placement of radiant pipe to correspond to areas of major heat loss is the key to providing uniform comfort levels. The use of adequate tailpipe is the key to high combustion efficiency and proper operation of the vacuum pump.

a. Radiant Pipe

The considerations in selection the length of radiant pipe include the following:

Minimum: This provides for the highest level of average intensity per foot of radiant pipe and good uniformity between burners. This requires more tailpipe to maintain operating efficiency and pump capacity.

Maximum: This provides the lowest average value of intensity per foot of radiant pipe, and consequently the largest span between burners. The intensity will be reduced slightly for the last 5-10 ft. of radiant pipe before the next burner.

The length of radiant pipe required for burners varies according to the firing rates. Also, consideration has been give to usage of a standard 10 ft. length or lengths that can be cut from same without waste. Refer to Table 2.

When positioning radiant pipe to give the required radiant distribution it is important to consider:

- Clearances to adjacent combustible materials.
- Lighting equipment.

b. Tailpipe

The considerations in selecting the amount of tailpipe include the following:

Minimum: This is the minimum length of tailpipe to cool the flue gases sufficiently for proper operation of the vacuum pump. Excessive temperatures at the inlet to the pump will reduce the effective flow capacity and the vacuum obtainable in the system.

Maximum: The maximum limit established for the amount of tailpipe that can be used is defined in Table 2. This permits the use of an extended connecting length of tailpipe if a branch of burners is remotely located which would otherwise require a separate vacuum pump. It should be noted that if there are traces of corrosive contaminants in the combustion air, much of this longer section of tailpipe will be exposed to the corrosive conditions due to low temperature in the end of the tailpipe.

In regard to the length of tailpipe required per flow unit, there is a trade-off between length of radiant pipe and length of tailpipe. Consequently, the recommendations for tailpipe are stated below:

Tailpipe Length (with recommended or maximum length of radiant pipe)
Minimum 1.2 ft./Flow Unit
Maximum 2.5 ft./Flow Unit

Tailpipe Length (with minimum length of radiant pipe)
Minimum 2.0 ft./Flow Unit
Maximum 3.0 ft./Flow Unit

Note: The maximum tailpipe for the model EP-100 pump is 1.7 ft./Flow Unit. Operation of the pump in excess of 1.7 ft./Flow Unit will cause permanent failure of the assembly.

Figure 7 relates the effect on system thermal efficiency of variations in radiant an tailpipe lengths. The chart was created based on test data obtained in accordance wit methodology developed by the National Bureau of Standards (NBSIR 80-2110) and rec ommendations on flue loss calculation contained in ANSI Z83.6 (latest edition). Actua installation variables (gas BTU content, air temperature and operation cycle, etc.) ma effect efficiencies (positively or negatively). As such, Figure 7 is presented as a guide t the designer for information only.

Note: When accounting for the required tailpipe lengths during the design process it is important to verify that the tailpipe for each branch is at least equal t the specified minimum.

For radiant branches which are served by shared tailpipe section, the shared section can be allocated to either branch with any distribution of length. The objective is to allo cate the shared section in a way which permits the minimum length requirement to b met for all radiant branches served by that shared section. **The prime consideration i that each foot of shared section can be counted only once.**

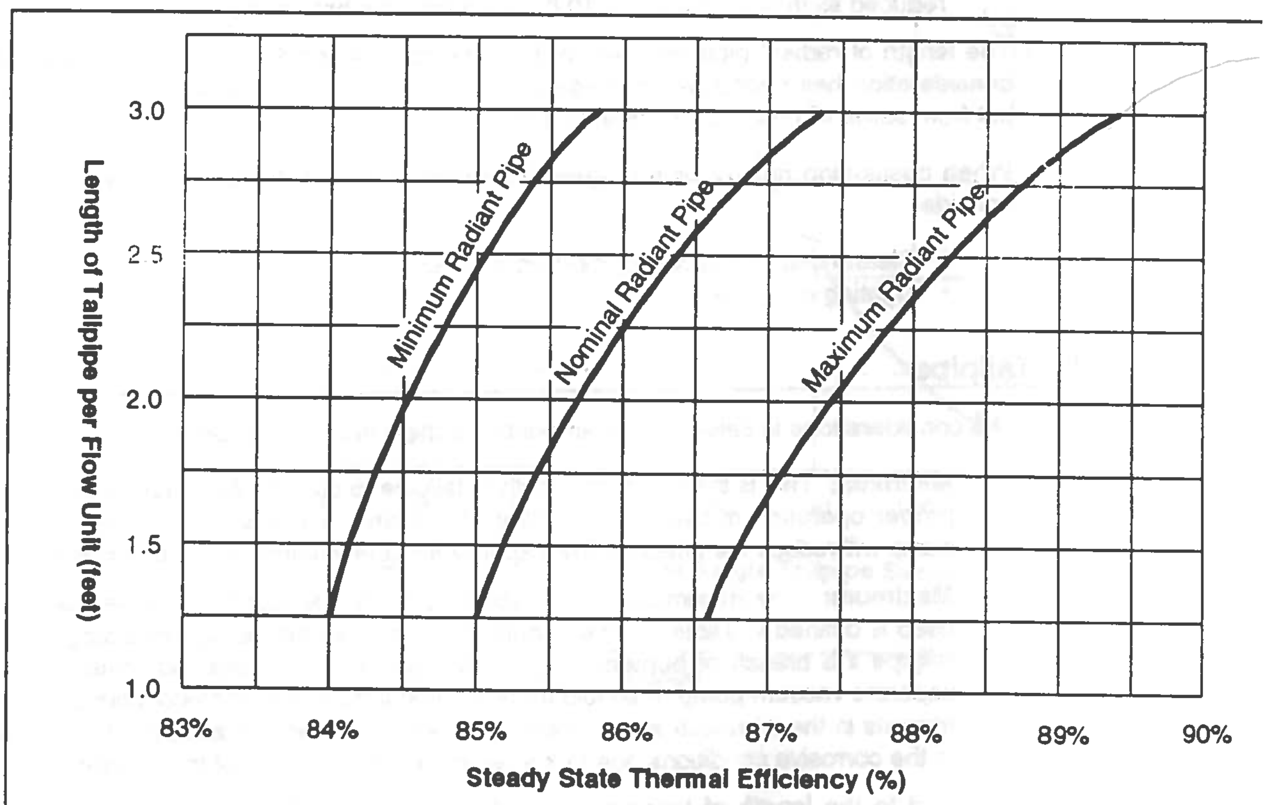


Figure 7: Tube Length vs. Efficiency

Figure 7 Note: Thermal efficiency values shown do not include the contribution due to condensing conditions when operating in cyclic fashion. To estimate cyclic efficiencies add 2-3% to the values obtained from the graph

7. Selecting a Control System

All Co-Ray-Vac systems may employ a solid state electronic control panel. In addition to providing system management, the control panel can also be used to provide individual zone temperature control for up to four zones. The control panel is required on large systems (as defined by electrical requirements) and optional on small systems. Small systems can use a thermostat and relay, which can also provide zone temperature control for up to two different areas.

a. Control Methods

There are three different ways to control a Co-Ray-Vac system:

1) **Electronic Control Panel** (P/N 02770001)
   With a single 20 amp, 120V supply can operate the vacuum pump and all burners with in a system with up to four zones. Required for use with SmartSet Energy Management System

2) **SPDT Transformer Relay** (P/N 90417600)
   With a single 20 amp, 120V supply can operate the vacuum pump and up to 9 burners in a system with only one zone.

3) **DPDT Transformer Relay** (P/N 90436300)
   With a single 20 amp, 120V supply can operate the vacuum pump and up to 9 burners in a system with up to two zones.

Low-voltage thermostats (24V) should be used. Thermostats that draw power from the system must not be used with the control panel, since the control panel provides only 5V of power to each thermostat.

A Vacuum Proving Switch (P/N 90430600) is required to interlock vacuum pump operation. The EP-200 pump includes an integral Centrifugal Motor Interlock which may be used in addition to the vacuum proving switch.

A Vacuum Proving Switch (P/N 90434500) is also required on the inlet duct of a non-pressurized air supply. For pressurized outside air supplies, the outside air blower motor has a Motor Interlock that must be used. These controls must be wired in series with the Vacuum Pump Interlock/Proving Switch.

When using an outside air blower either with a control panel or relay transformer, a separate Load Relay Package (P/N 05023000) is required. The control for the relay must be wired in **parallel** with the vacuum pump. The power must be supplied by a separate 20amp, 120V power supply.

b. SmartSet Energy Management System

Systems requiring energy management should employ the optional Smart Set Energy Management System (P/N02770101). The SmartSet is a microprocessor-based control system that installs directly on the Electronic Control Panel.

SmartSet Specification:

- System continually monitors the demand for heat and automatically regulates the burner firing cycles accordingly to provide for maximum comfort and fuel efficiency.
- System includes a 365 day time clock providing for automatic holiday programming and night set-back with four change-of-state points per day per zone.

- Emergency battery backup is included to prevent program loss on power failure
- System is capable of operating up to 4 independent heating zones.
- Programming is easily accomplished via an LCD/Keypad interface included as standard.
- Service and installation of the SmartSet is accomplished via easy "plug-in" access, and shall not prevent system from operating in a standard fashion.

8. Air Supply System

An air supply free of dust and corrosive contaminants is essential for proper operatic and best life expectancy with any heating system. With Co-Ray-Vac there are two alte natives available to the designer for providing the air supply. These are:

- Individual filter for each burner. A single filter door is standard for each burner.
- Outside air system to duct air from an uncontaminated source. A single filter for each burner is used plus outside air supply to provide both combustion and end vent air. It must be determined that outside air is not contaminated by exhaust from the same building and/or neighboring buildings.

The first alternative above is usable when the dust load is not excessive and there is ı usage of corrosive contaminants such as solvents or vapors inside the building or close proximity to the building. Vapors in close proximity could include exhaust air from nearby factory such as a chemical plant, a dry cleaning establishment, etc..

The second alternative must be used in all applications where corrosive contaminan may be present in the air in trace amounts (few parts per million) for several days or mo per year during the heating season.

It is important for designers and owners of heating systems to note that the presence traces of corrosive contaminants in the combustion air supply will greatly accelerate tl rate of corrosion on heat exchanger surfaces and will shorten the useful life of the heatir system accordingly. This is true regardless of whether the heating system is Co-Ray-Va other infrared systems or conventional gas or oil-fired equipment such as unit heatei central boiler plant, etc..

With Co-Ray-Vac it is practical to provide an air supply system for filtered combustion ɛ without any possibility of upsetting the fuel/air mix as the filter loading increases. With tl unique vacuum powered burners, the fuel/air mix remains constant.

It can be expected that the use of an outside air system will reduce but not eliminate tl corrosion.

In a way similar to the Co-Ray-Vac vacuum pump system, the design of the air supply sy tem also involves considerations of total flow units and acceptable combinations of dı lengths (and diameters) versus flow units carried. In certain circumstances it may be des able to introduce an outside air blower to pressurize the system. The small positive pre sure is desirable and necessary to prevent the system from drawing in contaminated air.

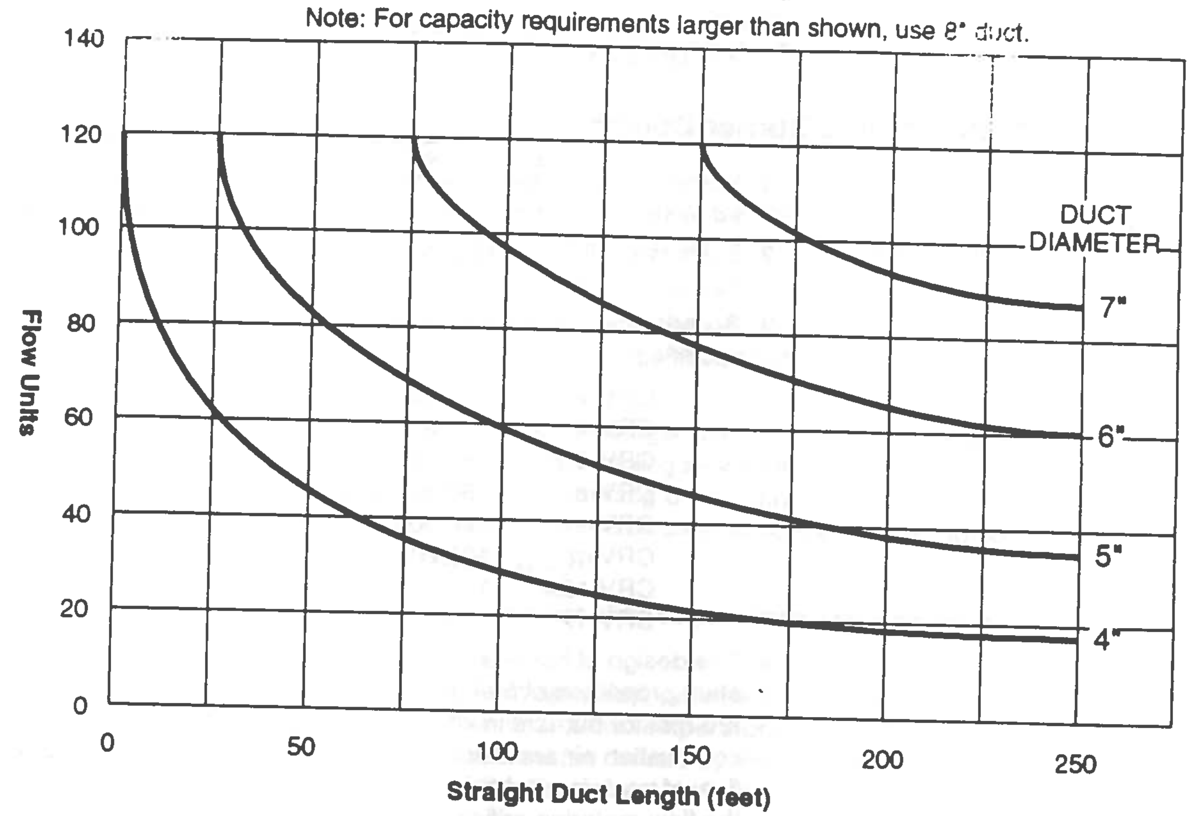


Figure 8: Air Supply System Capacity by Duct Length and Diameter
(Based on 0.25" w.c. maximum line loss)

To size each section of pipe proceed as follows:

- Calculate the required flow units at each outlet of the supply system.
- Measure the longest run of pipe from the blower to the most remote outlet. Use only this distance in Figure 8 (or the next longer distance if the exact distance is not shown). This is to provide assurance that the pressure drop to the most remote outlet will not exceed 0.25" w.c. when all outlets are supplied.
- To use Figure 8, find the intersection point on the graph for the appropriate duct length and number of flow units. The duct size **above** this intersection point indicates what size duct work should be used. Proceed in a similar manner for each outlet and each section of duct. For each section of duct, determine the total flow unit capacity supplied by that section.

10. Co-Ray-Vac Equipment Specifications

The total heating system supplied shall be design certified by the American Gas Association and this per American National Standard Z83.6 (latest edition).

A. Burner and Burner Controls

1. Burners shall be designed to fire simultaneously in series without adverse effects from combustion gases from upstream burners.
2. Burners shall be capable of firing with one of the fuel options as specified on the purchase documents: Natural Gas, or LP.
3. Burners shall be supplied to fire at any one of the input firing rates as specified:

CRV-2	20,000 BTU/Hr.
CRV-4	40,000 BTU/Hr.
CRV-6	60,000 BTU/Hr.
CRV-8	80,000 BTU/Hr.
CRV-9	90,000 BTU/Hr.
CRV-10	100,000 BTU/Hr.
CRV-12A	110,000 BTU/Hr
CRV-12	120,000 BTU/Hr.

4. The design of burners supplied shall provide for maintaining a constant proportion of fuel gas to filtered combustion air. These conditions are met for burners in which the pressure of both the fuel gas and the combustion air are introduced at zero (atmospheric) pressure and the flow of each is established by a vacuum on the downstream side of the flow metering orifices.
5. To assure a high degree of fail-safe operation, the design shall preclude flow of gas if any or all of the following abnormal conditions occur in the non-firing mode:
   a. Main valve fails in open position.
   b. Vacuum pump motor fails to operate.
   c. Power fails.
6. To further assure a high degree of safety, the system will be under negative pressure at all times during operation to preclude the possibility of the escape of combustion gases inside the building.
7. The burner control assembly will always include a zero regulator.

B. Equipment

1. **Burner**
   a. Each burner assembly shall consist of heavy-duty cast-iron burner heads, pre-wired gas controls with electronic, three-try direct spark ignition and combustion air filters.
2. **Vacuum Pump**
   a. The housing shall be heavy-duty cast-iron. (Or 16 gauge stamped steel for small systems as defined by vacuum requirements.) The impeller shall be cast aluminum alloy dynamically balanced and mounted for direct drive on the motor shaft.

b. The vacuum pump shall be acoustically isolated from the system with a flexible connector with temperature rating of 350°F minimum. The motor in the vacuum pump shall be secured with rubber mounts for acoustical isolation.

c. Vacuum pump motor shall be 115/230V, 60 Hz, 3450 rpm, TENV, with capacitor start, sealed ball bearings and thermal protected.

3. **Heat Exchanger**

a. Radiant tubing (between burners and 10 - 70 feet downstream of last burner) shall be of 4" O.D. steel or heat treated aluminized tubing.

b. The balance of the tubing shall be 4" O.D. steel tubing with an internal coating of acid-resistant porcelain. (Internal/external coating optional.)

c. All heat exchanger (tubing) connections shall be made with stainless steel coupling assemblies. Unlined couplings will be used with uncoated tubing or to connect uncoated to coated tubing. Lined couplings will be used to connect coated to coated tubing.

4. **System Control**

a. All burners shall be pre-wired with a grounded electrical cord and plug.

b. When specified, provide a solid-state electronic control panel to facilitate zone temperature control for up to four zones. Smaller systems (as defined by electrical requirements) may be controlled with a thermostat and relay.

c. Optionally provide the microprocessor-based SmartSet™ energy management system to facilitate heat programming and set-back features.

5. **Outside Air**

a. When specified, in contaminated environments, the system shall be capable of supplying air from the outside to each burner and end vent for the support of combustion.

C. Special Short Clearances Models

Where specified provide burner configurations capable of reduced clearances to combustibles in height-critical applications.

1. CRV "SC"

System shall consist of 1-3 branches with two CRV B-9 burners per branch. The first section of tubing downstream from each burner shall be heat-treated aluminized. Systems configured this way will be eligible for reduced clearances to combustibles. System is approved for use with 30 ft. of tailpipe per branch when maximum radiant pipe is used.

2. CRV 12/12A End Burner Only

System shall consist of 1-4 branches with one CRV 12/12A burner per branch. Systems configured this way will be eligible for reduced clearances to combustibles.