Power Flame Incorporated

THE CX TANK HEATING SYSTEM
CX SYSTEM APPLICATIONS
& MARKETING MANUAL

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C O N T E N T S

SECTION 1 - **INTRODUCTION**

1.1. OVERVIEW

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1.1.2. Applications
1.1.3. Market Opportunities

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1.3. CX SYSTEM TERMINOLOGY

1.1. OVERVIEW

The Power Flame CX series burners feature an innovative technology which applies to the heating of liquids used throughout commerce and industry. The system requires no combustion chamber and a minimal intrusion into tank or vessel working areas. CX burners operate directly into a small diameter immersion tube heat exchanger which is submerged in the liquid to be heated. The immersion tube varies in size from 1.5" to 6" nominal I.D.

1.1.1. POWER FLAME ADVANTAGES

* High efficiency (in excess of 80%) heat transfer. Other systems typically operate at efficiencies 20% to 30% lower.

* Multiple burner installations can be designed to operate with a common fan.

* Smaller diameters and shorter lengths of heat exchangers permits compact vessel designs, reducing installation, heat exchanger construction and chemical costs.

* Lower maintenance costs. No moving parts on burner housing so systems should only require annual maintenance after initial adjustment.

* Rugged construction with no exposed operating parts or electrical connections allows CX burners to operate in a wide variety of process environments.

* Computer generated POWER FLAME Cx CALC™ produces immediate and comprehensive responses to application requirements.

1.1.2. APPLICATIONS

Typical applications include a wide range of aqueous solutions and other liquids such as:

Acids	Chromates	Lubricating Oils
Alkali Cleaners	Cooking Oils	Phosphates
Beers	Demineralized Water	Water
Brighteners	Detergents	Waxes

These applications exist in market areas which include:

Metal Finishers	Hospitals	Food
Appliance Manufacturers	Colleges	Drink
Original Equipment Manufacturers (OEM)		

1.1.3 MARKET OPPORTUNITIES

The high efficiency of the Power Flame CX system opens up completely new marketing possibilities including the replacement of inefficient steam systems, old fashioned gas heating arrangements and expensive to run electrical systems.

The compactness of the Power Flame CX system introduces gas to new market areas such as hot water production in hot water storage tanks, mini breweries, etc.

Typical equipment payback periods are 3-24 months.

Replacing other heating systems with the CX system will pose few problems as the attachment requirements to the tank are simple. To the experienced gas start-up technician, setting up the burners is also straightforward and little different from other gas fired burner equipment.

1.2. WHAT AN END USER NEEDS TO KNOW ABOUT THE CX SYSTEM

Heating liquids in industry and commerce is an expensive operation. The combined use of a high efficiency heating system utilizing a competitively priced fuel offers the end user the most cost effective method of process liquid heating.

The CX burner system offers this particular combination. Operating efficiencies are designed to be in excess of 80% for all aqueous heating applications and the burners operate on either natural or L.P. gases.

COMPARISONS WITH OTHER HEATING METHODS

1.2.1. Steam/Hot Water
1.2.2. Electricity
1.2.3. Gas

1.2.1. **STEAM/HOT WATER**

Process tanks are often heated by steam or hot water supplied by a central boiler plant.

Four principal methods of secondary heat exchange within or adjacent to a tank are commonly used:

1. Steam coils or plates within the process tank.
2. Heat exchangers external to the process tank.
3. Water jackets around the process tank.
4. Direct steam injection into the process tank or water jacket.

Disadvantages of this type of arrangement are:

1. Relatively Low efficiency.
2. Limited controllability and flexibility.

TRANSMISSION INEFFICIENCY

a. Many central boiler plants are located a considerable distance from the point of application of their steam or hot water outputs.

   If a boiler itself is operating at an efficiency of 75%, it will probably lose in excess of 10% of its output over the transmission network between the boiler location and the process tank. If a coil or plate heat exchanger is in use within the tank the secondary heat transfer efficiency is likely to be in the region of 80%.

A combination of these three heat exchange ratios results in an overall system efficiency of approximately 54%.

Therefore for every 1 BTU of heat required by the process tank, 1.85 BTU of fuel input is required at the boiler.

b. Where boilers have seen better days or where transmission pipework is poorly insulated, even a 54% overall efficiency level may not be possible. The cost per useful BTU of heat input will then be proportionately higher.

CONTROL INEFFICIENCY

Close control of liquid temperatures can be difficult with these indirect heating methods. Many plants have to cope with components of various sizes passing along an individual production line. It is particularly necessary in these instances that the process heating equipment respond quickly to the sudden changes in heat demand that will occur.

CENTRAL SYSTEM TURNDOWN INEFFICIENCY

A central boiler usually supplies energy for more than one application. Often factory space heating is achieved by using steam or hot water unit heaters or radiant panels. During summer months when space heating is not required, it can be extremely inefficient and costly to maintain boiler operation at partial load for process requirements which pertain only to the heating of solution tanks.

There are also other costs associated with the operation of boilers which should not be overlooked. Chemical treatment of feed water and other operator costs must be considered.

1.2.2. ELECTRICAL SYSTEMS

Process tanks can be efficiently heated by using electrical immersion elements. The specific advantage of using electrical immersion units is their relatively low initial cost. They offer good control over liquid temperatures, require minimum maintenance and provide an extremely flexible approach to tank heating. Electrical immersion heaters can be assumed to operate at an efficiency level close to 100%.

The major disadvantage of electric immersion heaters is: CURRENT OPERATING COST IS HIGH AND GETTING HIGHER.

Electric heating is an attractive alternative only when the tank to be heated is either extremely small, used very infrequently or for some reason only at night, or when special rates can be made available.

1.2.3. GAS SYSTEMS

Natural gas has been used to heat tanks for a number of years. A number of methods have been employed, each with their own inherent advantages and disadvantages.

The three principal methods of gas fired tank heating are:

A. Underfiring.
B. Large diameter immersion tubes.
C. Small bore immersion tubes.

A. Underfired Systems

Underfired tank heating is perhaps the simplest and oldest method of heating industrial process tanks utilizing gas. Rows of natural draft bar burners are arranged beneath the base of each tank.

There are two principal disadvantages to this approach. First, the overall efficiency of such a system is usually extremely low. Efficiencies as low as 20% are not unusual. Second, the products of combustion are often released around the sides of a tank into the factory environment.

B. Large Diameter Immersion Tubes

Packaged forced draft or natural draft gas burners are used in conjunction with large diameter immersion tube heat exchangers. These tubes are installed in each process tank and can be up to 10-12 inches in diameter.

The burner is located on the "firing leg" of the heat exchanger, the products of combustion are exhausted, usually to atmosphere, from the "exit leg".

These systems again have a number of drawbacks:

a. The overall efficiency of the arrangement tends to be rather low and the surface temperatures extremely high.

b. A large diameter tubular heat exchanger takes up significant space within the tank because the heat exchanger shape must be kept simple in order to ensure that the pressure drop through the system is low.

c. Because of its required size, the cost of the heat exchanger will be very expensive if the process liquid requires that the tube be constructed from any material other than mild steel.

C. Small Diameter Immersion Tubes

Small diameter immersion tube gas fired tank heaters usually represent the best solution to the problem of selecting process tank heating equipment.

A forced draft burner can be used but, once again, the shape of the heat exchanger must be kept simple (i.e., a two pass configuration), so that the pressure drop through the tube can be overcome by the burner fan. High surface temperatures are an inherent part of this design.

The Induced Draft Power Flame CX burner system is the Best Possible Option.

The Power Flame CX system uses a specially designed matrix gas burner. The burner fires directly into the first leg of a small diameter heat exchanger which is usually shaped into a multi-pass configuration. A centrifugal suction fan is connected to the exit leg of the heat exchanger and the products of combustion are exhausted to atmosphere through a flue. (See Figure 1, page 47 and Bulletin CX-189.)

The suction fan is capable of overcoming substantial heat exchanger pressure drops. Heat exchangers can be designed to fit into a tank with little or no interference to the process. They can be arranged to lie horizontally across the bottom of a tank or designed to operate in a vertical position along the side walls. Coil heat exchangers can be used for cylindrical tanks.

The tubes are generally constructed from mild steel for water based or alkali heating applications, or from the various grades of stainless steel where more corrosive solutions such as acids or phosphates are to be heated.

The heat exchanger diameters range from 1.5" I.D. which is capable of handling a maximum input of 150,000 BTU/h, to 6" I.D. at a maximum rating of 2,500,000 BTU/h.

These ratings result in a relatively high intensity of heat transfer. It is therefore extremely important that the heat transfer rates along the complete length of any particular design of heat exchanger be calculated and examined to ensure that they do not exceed any pre-determined maximum.

Power Flame engineers use a computer generated model to carry out all the heating calculations associated with each tank heating application. The computer generated Power Flame Cx Calc™ is capable of producing the most efficient operating system for the stated operating parameters.

a. Information from the Survey Form (Figure 2, pages 48 and 49) is used to calculate the gas input required to achieve the tank's operating temperature within the specified warm-up time and the gas load during the working day, while the tank is being used for production.

b. A variety of heat exchanger designs can be tested. Each design is entered into the computer and the computer will model the performance of that design at the required gas input level.

c. The overall pressure drop of the finally selected, most efficient heat exchanger is calculated and compared to the exhaust fan specifications in order to allow for proper selection of the I.D. fan.

d. The temperature of the combustion products at the outlet of the heat exchanger, is estimated and the overall system efficiency calculated.

Each tank heating system is fully automatic. Early morning startup is usually under timeswitch control. An immersion thermostat switches the burner between a "high input" setting, i.e. the full burner rating and a "low input" setting when the process temperature has been reached. A 4-6 deg.F temperature differential is used as standard, using conventional thermostats. Closer control can be obtained by using electronic temperature controllers.

Because each system is self contained and independent, (even when a common fan is used) individual tanks can be used as and when required offering maximum flexibility to the specific production operation.

Each system is usually designed to operate at an efficiency level of 80%. The Power Flame small diameter immersion tube natural gas system can offer fuel cost savings of approximately 30% to 50%

compared to their respective central boiler and electrical alternatives.

1.3. CX SYSTEM TERMINOLOGY

Controls	:	Burner supervision equipment.
CX Burner	:	A cylindrical housing enclosing the burner head assembly, ignition and flame rectification electrodes. (U.V. scanners may also be used.)
Flue Gas Damper	:	A combustion air damper installed in the flue gas piping after the heat exchanger but before the inter-connection to either multiple exhaust pipes or the induced draft fan. (Damper may be motorized.)
Induced Draft Fan (Combustion Air Fan)	:	High pressure blower unit to provide suction through one or more heat exchangers.
Gas Train	:	Gas supply control system incorporating main and pilot (start) valves.
Heat Exchanger	:	Small diameter steel or alloy pipe (1.5" - 6" I.D.) that is immersed in the liquid to be heated.
Temperature Controller	:	Electronic Temperature control device (differential typically plus or minus 1 deg.F). Temperature display is optional.
Thermostat	:	Temperature control device (Typically plus or minus 5 deg.F)

NOMINAL RATINGS

Model	Exchanger Pipe Size	Input (BTU/Hr)	Burner Head Gas Pressure
CX15	1 1/2	150,000	2.0" w.c.

CX20	2	275,000	6.0" w.c.
CX25	2 1/2	475,000	2.0" w.c.
CX30	3	750,000	4.0" w.c.
CX40	4	1,500,000	6.0" w.c.
CX60	6	2,500,000	6.0" w.c.

Nominal Ratings are based on 4 pass heat exchanger configurations operating at a liquid temperature of 160 deg. F. Higher capacities may be obtained by using less heat exchanger passes or high pressure suction fans (consult Factory).

SECTION 2 - **CX SYSTEM APPLICATION**

2.1. CX SYSTEM LOAD CALCULATIONS & SURVEY GUIDELINES

2.1.1. Survey Form and Guidelines
2.1.2. Additional Background Information
- A - Internal Considerations
- B - External Considerations

2.1.3. Power Flame Cx Calc™
- A - Tank Heat Loss Computer Program
- B - Heat Exchanger Design Computer Program

2.1.4. The Job Estimate & Customer Proposal

2.2. ENGINEERING DATA

Burners
Gas Train Piping
Controls

Heat Exchanger Pipes *
Heat Exchanger Pipe Lengths *
Heat Exchanger Flanges *
Exhaust Dampers
Exhaust Fans
Temperature Control

*Note - Heat exchanger pipe designs will be included as part of the Power Flame system presentation. These designs must be followed exactly, using indicated pipe and bend types and radius shown, if performance/efficiency levels are to be maintained.

The heat exchanger shall not be supplied by Power Flame. Local fabricators can easily provide this requirement.

2.1. CX SYSTEM LOAD CALCULATIONS & SURVEY GUIDELINES

The success of each CX system application is totally dependent upon the attention that is paid to detail when preparing The Liquid Heating Survey Form (see Figure 2, pages 48 and 49). The Power Flame Cx Calc™ will use the information provided from the form to develop a formal computer generated presentation that will include:

a) Heat loss and load calculations.

b) CX system performance estimates.

c) Equipment quotations and running cost/payback analyses (when required).

2.1.1. SURVEY FORM AND GUIDELINES

One survey form should be completed for each tank unless either a series of tanks are exactly the same or there are only minor variations which can be noted on a common survey form.

SECTION A. Company, Address, Date, Name, Position, Telephone and Fax.

This data relates to the organization to whom the quotation is to be addressed.

SECTION B. Process Line : End user customer identification

Tank Identification : Name, number or reference for each tank to be considered.

SECTION C. Dimensions : Data for tank length, width, height and liquid depth is required in feet or inches.

(NOTE: If the tank is cylindrical or any other irregular shape, you must supply a complete sketch of the configuration (see Existing Heating System Sketch section of the survey form).

SECTION D. Insulation : Thickness in inches. It will be assumed that the tank base is not insulated.

Top Surface : Check boxes as appropriate. If lip (air) extract cfm is available please include as a note.

SECTION E. Contents : Information relating to liquid to be heated is required particularly if specific heat is other than 1.0 so that Power Flame can make -

1. Correct heat load calculations.
2. Recommendations for heat exchanger pipe material.
3. Advise if CX system is suitable for the application which is under consideration.

Note : The CX system is not normally suitable for the heating of highly viscous liquids such as asphalt. Convection in viscous liquids is greatly reduced compared with water based solutions and excessive pipe temperatures could result if the CX system is applied in these cases. This problem may be overcome, in some cases, by oversizing the heat exchanger, or heating less sensitive liquids which could then be used to heat the viscous fluid.

SECTION F. Solution Make Up : Information concerning the volume and temperature of any 'cold' liquid make-up which is used to maintain the liquid level within the tank.

(This section is not intended to provide information on supply and return, flow temperatures in 'pumped' systems - see SECTION I)

SECTION G. Product Flow : This section specifically relates to 'Dip Tanks' where a weight of material (and perhaps a supporting carrier such as a C-hook) are immersed in the tank.

If the tank is used to supply a hot liquid to a process then this data is not required, however, it may be useful to use this section to indicate information pertaining to use of the generated hot liquid. The required heat load calculations will be made from data inserted into subsequent sections.

Data relating to operating periods will permit running cost estimates to be computed.

SECTION H. Any Other Losses : This is the section where any other sources of 'heat loss' will be identified. These losses are usually associated with the temperature differentials that result from liquid flows to and from processes i.e. spray pre-treatment systems, hot water distribution networks, etc. This data is sometimes difficult to obtain, however, it is vital measurements should be taken in order to ensure accurate heat load calculation. (See Figure 3, page 50)

The following basic information should be submitted for such systems:

a) Volume of liquid that is flowing
b) Discharge temperature
c) Required return temperature

Example: Flow Rate : 300 gallons/minute
Discharge temperature 160 deg.F
Return temperature 153 deg.F

The heat load will then be computed as follows -

Q = 300 gallons/minute x 60 minutes/hour x 8.3lb/gallon x 7 deg.F differential.

Q = 1,045,800 BTU/h.

PLEASE NOTE: In this example, for every 1 deg.F temperature differential the heat load is 149,400 BTU/h. Under or over statements of temperature differentials can easily therefore make the heat load calculations inaccurate.

A useful 'rule of thumb' to remember -
1 gpm = 500 BTU/h/deg.F differential.

Where 'air agitation' is used to aid liquid circulation within a tank the cfm and temperature of the compressed air should be noted under this section.

SECTION I. Operation : 'Heat up time' is the maximum time permissible to raise the tank temperature from 'cold' (please state 'cold' temperature - 50 deg.F will be assumed unless otherwise advised).

NOTE: 1) Most tanks will be subjected to 'cold' temperature only after extended shutdown periods or following cleaning and re-filling.

2) It will be assumed that any

air extraction systems will not be in operation during the warm up phase. It will also be assumed that no production will take place until the desired tank temperature has been attained.

SECTION J. Existing System (where applicable)

Data inserted in this section is used to -

a) cross check heat load calculations (particularly useful in association with Section I above)

b) provide base data used to produce efficiency comparisons between the CX and the existing heating arrangement. This information is, of course, necessary if a project pay back analysis is required.

SECTION K. Fuel & Electrical Requirements

Please give as much information as possible on fuel types and pressures together with available electrical supply data so that correct sizing (and costing) of gas train components can be made and suitable motors for exhaust fans selected.

SECTION L. Existing Heating System Sketch

Individual tank details, possible heat exchanger pipe orientation/limitations, tank groupings, basket/load dimensions, etc. can be shown. Where multiple tank heating systems are to operate using a common exhaust fan please show preferred layout here.

SECTIONS M. AND N. Reasons for Consideration of Change of Heating (where applicable) and Additional Comments.

Please provide any other useful background information which could have a bearing on -

a) heating system selection/sizing
b) type of presentation required

2.1.2. **ADDITIONAL BACKGROUND INFORMATION**

Below are listed a series of points that should be used as a 'Check List' when surveying a new project. Many points particularly relate to the ultimate installation of a new CX system or series of systems.

A. **INTERNAL CONSIDERATIONS**

1. Tank Material - Useful to note : usually heat exchanger pipe material is similar.

2. Existing Heating System Material - Again a good indicator of what heat exchanger pipe material will be suitable.

3. Tank Linings - Is inside of tank lined with rubber, glass fibre etc. Why? Usually an indicator of an aggressive liquid and therefore care will be needed when heat exchanger pipe material is selected.

4. Heat Exchanger Sealing - Two alternative forms of heat exchanger sealing are recommended

a) Flange mounting
b) Plate mounting
(Figure 9, page 55)

Both require that a gasket is fitted to make a liquid tight seal. Butyl rubber is the usual selection.

Note: Certain chemicals may attack Butyl rubber - Modifications to more appropriate material may be required.

The welding of heat exchanger pipes to tank walls is not recommended. While this method of installation will not affect the system performance, the pipes will not be removable should either failure occur or if severe scaling requires 'out of tank' cleaning.

5. Heat Exchanger Location - Heat exchanger pipes can be installed in any position, i.e. usually a selection between horizontal (parallel to tank floor) or vertical (adjacent to one or more tank walls).

They may be supplied as one complete assembly or flanged internally when required. The selection of a suitable position should include consideration of the following -

a) the liquid in the tank must cover the heat exchanger at all times. If necessary investigate the supply of a liquid level switch to protect the burner system against low liquid and/or to operate an automatic liquid filling arrangement.

b) obstruction to any work loads (always determine maximum outside dimensions of any work loads for dip immersion tanks and method of suspension/support of work loads when immersed to provide necessary clearance data for heat exchanger pipes).

c) possible build up of chemical 'sludge' on tank floor. The heat exchanger must remain clear of any sludge at all times as a loss of heating efficiency and severe overheating of the heat exchanger material will result from any submersion within sludge deposits.

d) will internal or external tank bracings (if any) obstruct mounting flanges or mounting plates?

e) can the heat exchanger be physically fitted into the tank, investigate headroom, and external clearances from walls, etc.

NOTE : Do not overlook the access requirements at the site necessary to bring the heat exchanger from outside to the tank location.

f) ease of providing any necessary protection to the heat exchanger.

g) heat exchanger support options.

6. Temperature Sensors - Note suitable location for temperature control sensor well and select appropriate type and length of the well.

B. **EXTERNAL CONSIDERATIONS**

1. Tank Position

- Note if there is adequate clearance to fit and maintain CX burner equipment. Take particular care if tank is located in a 'pit'.
- Note if the atmosphere surrounding burner area is 'aggressive'. Particular care should be taken where either hot or cold acid tanks are situated in the area. (End user must use adequate air exhaust systems to ensure that corrosive vapors do not 'lie' at low levels).
- Note if burner will require ducted combustion air and if necessary determine suitable

routing.

- Note if the burner will require protection from splashing, personnel or possible mechanical damage.

2. Tank Support

- Note if tank is located directly on the floor or supported by steelwork. Measure clearance from floor.

Important : CX series burner diameters are larger than mounting flange diameters. Therefore in cases where heat exchanger mounting flanges are required to be close to tank bottom ensure there is adequate space available to accept the burner diameter at the outside of tank.

3. Gas Supplies

- Note exact type of gas to be used
  i.e. Natural : Heating value.
  LPG : Propane or Butane heating values and specific gravities.
- Note position of gas supply and anticipated pressure available at first valve in the gas train.
- Note intended location for gas train. (If train is to be pre-piped - Optional Feature)

4. Electrical Controls

- Note best position for burner controls panel.

5. Exhaust Pipework

- Can a common exhaust fan be used for a number of CX burners?

- Determine optimum route for exhaust pipework from exhaust damper to exhaust header (if applicable) and on to a selected position for the exhaust fan.

- Determine exit route for exhaust flue after the exhaust fan bearing in mind flue support requirements.

- Determine whether exhaust pipework needs to be insulated (usual exhaust temperatures will be in 375-525 deg.F range).

2.1.3. **POWER FLAME Cx CALC™**

Upon receipt of completed 'Liquid Heating Survey Forms' and any associated support documentation, Power Flame engineers can quickly calculate heat losses and prepare suggested CX system equipment design options.

A. **Tank Heat Loss and Heat Exchanger Design Program**

The Power Flame 'Tank Heat Loss Computer Program' provides a comprehensive statement of the heat loads which will result from -

Production Heat Losses - Heat losses involved during normal production operation (when liquid has been warmed to operating temperature).

Wall Losses
Surface Losses
Make Up Losses
Production/Carrier Losses
Other Losses

Warm-Up Loads - Heat Loads involved to bring liquid from pre-defined "cold" temperature to operating temperature.

A Computer Generated Printout will be provided for each application, outlining specifically both warm up heat load and production heat losses (see Figure 3A, page 51).

Often 'Warm Up Loads' are considerably greater than the anticipated 'Production Heat Losses' because many customers will request short warm up time periods. 'Short' warm up periods should only be requested when the process requires a particular warm up period or when a 'manual' start dictates a specific time between system on and production operation start.

B. **Heat Exchanger Design Computer Program**

After both the 'Production Heat Losses' and 'Warm Up Loads' have been determined, Power Flame engineers can select a possible CX burner system together with a proposed heat exchanger configuration. Various possible heat exchanger configurations can be modeled to produce the most efficient design, using the "Heat Exchanger Design Program'.

Data is inserted relating to the following -

1. Quotation or Project Reference
2. Heat input (Gross gas input - whichever is the greater, the Production Heat Losses or the Warm Up Load).
3. Liquid Temperature
4. Pipe size and wall thickness (see Figure 5, page 52)
5. Pipe configuration incorporating long radius bends or mitred joints (not often used due to high pressure drops). (See Figure 4, page 53)

   Consideration is given to the maximum permissible pipe lengths (weld to weld) (See Figure 4, page 53) and mounting flange dimensions (See Figure 17, page 54).

The computer program then 'models' the anticipated performance by breaking down the total proposed heat exchanger into a number of zones (each equivalent to 'one pipe diameter') and by carrying out heat exchange calculations at every zone.

A second print out is then produced (See Figure 10, page 56) which indicates the expected efficiency and flue gas temperature, together with a proposed heat exchanger design configuration. The developed heat exchanger design and associated pressure drop are then used to determine the appropriate exhaust fan selection.

Alternate heat exchanger configurations can easily be 'modeled' using the program so that different heat exchanger design options can be made available.

2.1.4. **THE JOB ESTIMATE & CUSTOMER PROPOSAL**

The Power Flame quotation proposal will incorporate data as noted in Figure 3A, page 51 and Figure 10, page 56, and shall include cost to supply the following basic system components:

CX Burners
Gas Trains (Pre-piped Optional)
Burner Controls (Motorized Optional)
Exhaust Dampers
Exhaust Fans
Temperature Controls (Aquastat or Electronic)

The quotation will include a restatement of the essential design criteria extracted from the Survey Form

i.e. Tank Dimensions
Insulation and Top Surface Data
Operating Temperature
Product Flow Data
Solution Make Up
Other Losses (i.e. Spray Rates and Temperature Differentials)
Warm Up Times (and Starting Temperature)

Any assumptions made will be highlighted. We strongly advise that this restatement of essential design criteria be passed on to the client in the final proposal, in order that he may review, modify as require, and formally accept the parameters of design being offered. When required and provided sufficient data has been included on the original survey form, efficiency comparisons can be made between the CX system proposal and that of the equipment currently in use. Fuel consumption and running cost comparisons can then be made which when limited to the overall end user project cost (i.e. including heat exchanger supply + installation + start up costs) will provide the client with a basis upon which to make a project pay back analysis.

SECTION 3. **SELLING THE CX SYSTEM**

3.1. INTRODUCTION

3.1. **INTRODUCTION**

This section highlights the principle market areas and types of customers who should have real interest in CX system applications.

The CX system has been available in Europe for well over 10 years. Originally developed by Dunlop in the l970's, in conjunction with British Petroleum, the system has proved itself to be a market leader with process gas engineers who express a clear preference for our system compared to the alternate large diameter or forced draft application.

The specific advantages of the CX system will be highlighted and ideas as to how they might be fully exploited will be explained.

3.2. MARKET AREAS

PRODUCT FINISHING
FOOD AND DRINK
OTHERS

3.2.1. PRODUCT FINISHING

The prime market place for CX tank heating systems is in the product finishing industry. This industry is split into two basic areas.

(1) Those manufacturing companies that incorporate 'in house' product finishing processes.

(2) Material finishing companies who supply product finishing services to manufacturing companies.

The most common materials which require finishing are -

A. Metals
B. Wood
C. Plastics

Of these, metal finishing is by far the largest sector with potential applications for the CX burner system.

A. Metal Finishing

The main areas which have the greatest number of liquid heating applications are -

1. <u>PRE-TREATMENTS</u>

   Chemical degreasing and cleaning (including ultrasonic)
   Pickling
   Phosphating
   Chromating

2. <u>TREATMENTS</u>

   Anodizing (Sulphuric, chromic, hard, bright and color)
   Electroplating

1. <u>PRE-TREATMENTS</u>

   <u>Chemical Degreasing & Cleaning</u>

   Grease, oil or other contaminants must be removed from a surface prior to final treatment whether this be electroplating, painting, anodizing, etc.

   The pre-treatment processes immediately prior to final finishing generally take the form of hot alkali degreasing/cleaning, possibly followed by acid dipping or pickling to remove any oxide films and then followed by a further rinse and/or alkaline cleaning.

   Degreasing can also be accomplished using either cold or hot solvents such as

   TRICHLORETHYLENE.
   THE CX SYSTEM IS NOT SUITABLE FOR HEATING SOLVENT DEGREASING SYSTEMS.

The choice of a hot alkaline metal cleaner is influenced by the material to be cleaned and also the type of soil or grease to be removed. As a rule the higher the alkalinity the more rapid the cleaning.

The common metals cleaned fall into the following groups -

1. Steel
2. Copper, brass, nickel, silver and other copper based alloys, magnesium and its alloys.
3. Zinc based alloy, tin and tin alloys.
4. Aluminum.

For alkaline cleaners a welded tank is normally used. Plastic lined, rubber lined, as well as plastic or fiber glass tanks can also be used, subject to temperature limitations.

Small components may be immersed in a basket or barrel. Larger components are suspended from overhead C-hooks or other hanging devices.

The process can take the form of either a 'dip' or a 'spray' process.

In ultrasonic cleaning the penetrating power of the cleaner is accelerated by using high frequency sound waves. CX system burners are ideally suited to the heating of alkali cleaning tanks. Usually mild steel heat exchangers will be adequate.

Pickling

The term 'pickling' refers to the process of cleaning in acid, usually for the purpose of removing oxide or scale.

Articles which have been drawn, pressed or spun from bright cold rolled sheet without anodizing retain their bright finish and require little or no pickling, but parts that have been heat treated may have scale or oxide which must be removed from the surface before the next operation.

Descaling may be done by either pickling or shot blasting.

Sulphuric acid is commonly used for the pickling or descaling of iron, steel, copper, brass, nickel, silver and other copper alloys.

The acid may be contained in a lead lined or rubber lined welded steel tank.

CX heating systems can be used for heating pickling tanks <u>provided the heat exchanger material is carefully selected</u> in consultation with the end user and chemical supplier. Tanks containing hydrochloric acid are not usually suitable for heating using the CX system.

In order to avoid corrosion of burners, gas trains and electrical controls, an appropriate exhaust system must be used to ensure that acid vapors are removed from the environment.

Phosphating

Phosphate coatings have a wide range of applications in manufacturing industry as an aid to mechanical production operations and in surface finishing.

Three main types of phosphate are used -

Zinc Phosphate
Iron Phosphate
Manganese Phosphate

The major applications for phosphate treatments are :-

a) the pre-treatment of surfaces to be painted or powder coated in order to provide improved coating adherence.

b) for protection against atmospheric corrosion.

c) to provide resistance to wear, scuffing and to aid running-in on rotating or sliding surfaces.

d) to act as a lubricant as a production aid in cold metal working operations such as cold forming and wire drawing where the treatment
   - eliminates metal to metal contact.
   - cushions the metal surface thus reducing the possibility of scoring or scratching.
   - provides a surface which retains the oil or lubricant in place so that it flows with the metal during the forming process.
   - enables a 'drawing' operation to run at a faster speed.

Phosphating can take place in either 'dip' or 'spray' plants. Conveyor spray and dip phosphating plants which incorporate the cleaning and rinsing stages are in wide use throughout the manufacturing industry for the processing of components prior to painting of consumer durables such as washing machines, etc.

Immersion phosphate treatments may be accomplished with the articles mounted on jigs or racks. Small components may be carried in baskets or barrels.

Spray phosphating is used for rapid and lighter coating processes. The articles to be processed are mounted on jigs or individually hung and carried by conveyor through a 'tunnel' which incorporates the various pre-treatment stages. In many cases the conveyor ultimately carries the product on to a drying stage where there may well be further application areas for Power Flame burner equipment. Each process stage incorporates a number of jets arranged on risers. The solution after spraying returns through ducts in the tunnel floor back to the liquid holding tank.

THE HEAT LOSSES FROM THESE APPLICATIONS ARE OFTEN DECEPTIVELY HIGH. PLEASE REFER TO SECTION 2.1.1 FOR A DESCRIPTION OF THE SURVEY REQUIREMENTS FOR SPRAY SYSTEMS.

Tanks for zinc and manganese phosphates are usually constructed from stainless steel (grade 316 - EN58J). Iron phosphate can be contained within mild steel tanks.

PHOSPHATING PROCESSES CAN PRODUCE SLUDGE AND/OR SCALE WHICH -

A) BUILDS UP ON THE TANK FLOOR

B) ADHERES TO HEAT EXCHANGER SURFACES.

HEAT EXCHANGERS MUST THEREFORE BE -

A) POSITIONED ABOVE THE ANTICIPATED SLUDGE LEVEL.

B) BE ACCESSIBLE FOR CLEANING WITHOUT REMOVAL.

C) ON THIS TYPE OF APPLICATION, WE SUGGEST THE INSTALLATION OF A STACK TEMPERATURE ALARM DEVICE THAT WOULD ALERT THE OPERATOR THAT HIS HEAT EXCHANGER SURFACES WERE BEGINNING TO DEVELOP A SERIOUS SCALE BUILD UP AND SHOULD BE CLEANED.

IF STAINLESS STEEL HEAT EXCHANGERS ARE USED IT MAY BE APPROPRIATE TO POLISH THE OUTSIDE SURFACE (EITHER MECHANICALLY OR PREFERABLY BY ELECTROPOLISHING) SO THAT CLEANING IS MADE EASIER (USUALLY BY MEDIUM/HIGH PRESSURE WATER JET, RUBBER OR WOODEN HAMMER/ SCRAPER).

(No hard implements should be used for cleaning polished pipes as once 'scratched' the polishing process is rendered ineffective and 'stronger' scale adhesion will result).

Chromating

Chromate treatments are applied to aluminum and zinc surfaces to provide an effective base for organic coatings and to improve the overall protective value of the coating system.

Chromate treatments are applied to steel, tin, copper and brass to render the surface passive and thus more resistant to corrosion or tarnishing.

Due to the wide variety of chromating chemicals and processes that can be used, it is not possible to comment on likely heat exchanger pipe material requirements. Therefore particular attention to this detail must be made when surveying a potential application.

2. TREATMENTS

Anodizing

Anodizing provides a protective and decorative film on aluminum.

The anodizing process is usually either based on sulphuric, chromic or exilic acids which are used as electrolytes within an electrolytic oxidation process.

Following pre-treatment the principle heat load in an anodizing process comes at the final 'Sealing' stage. Heating of the electrolytic solution is not usually required. (Should there be a requirement - refer to Electroplating Section). Boiling water is the usual method used to seal anodized aluminum. Distilled or deionized water is often used. Sealing water is contained within stainless steel tanks which require careful temperature control at 212 deg.F. It is therefore usual to incorporate accurate electronic temperature controls as part of the process heating system.

Electroplating

Electroplating is a process whereby an electrolytic deposit of a metallic coating takes place on to a base material, for decorative, protective and functional purposes. Typical deposits include cadmium, chromium, copper, nickel, tin, zinc, gold and silver.

The design and construction of electroplating plant is very critical due to the corrosive nature of many of the solutions used and because 'stray' electric currents can readily accelerate corrosion in materials which are normally resistant to corrosion.

Tanks for acid plating solutions are generally made of rubber-lined or plastic-lined steel, plastic or glass fiber.

Heating electroplating tanks using the CX system requires that the tanks be of sufficient size to justify the capital expenditure. Many electroplating installations use small tank arrangements.

The selection of heat exchanger pipe material is critical, as is the mounting position within the plating tank.

Generally the heat exchanger pipes should be located between the anodes and the tank wall. The pipes may be constructed from mild or stainless steel, titanium, zirconium, or other specialized alloys. A chemist (usually employed by the electroplater) should advise on the suitable material selection, its thickness and mounting position. He should also specify the gasket material which should be employed. Due to the aggressive nature of the chemicals concerned, it is important to ensure that there will be no serious contamination to the external burner components (i.e. burner, gas train and electrical controls) from vapors. (Adequate room ventilation must be provided).

Wood and Plastic Finishing

Application for CX system heating in these market sectors are relatively few.

Each application should be reviewed on its own merit with particular attention being paid to chemical type and therefore heat exchanger pipe material selection.

General comments included in the metal finishing pre-treatment and treatment sections apply.

3.2.2. **FOOD & DRINK**

The scope of the application of CX burner systems in the food and drink industries fall into three categories.

1. To heat liquids that are to be used for the washing of utensils, bottles, crates, floors, etc.

2. To heat liquids that are used in the pre-treatment processes prior to final production such as for pig or chicken scalding.

3. To heat liquids that are used in the actual food or drink production process, i.e. water for boiling, blanching, brewing; oil for frying etc.

Traditionally these processes have generally been heated by steam or hot water. However, there is now a considerable movement towards decentralization away from central boiler supply systems in order to obtain improved efficiency and operational flexibility.

Individual CX burner systems offer these advantages and provide a close temperature control capability which is often another major consideration.

Water based applications present few problems. However, care must be exercised when heating other liquids, such as cooking oils, where the heat exchanger pipe surface temperature must remain within specified limits so as to avoid any breakdown of the heated liquid. Specific guidance should be sought from Power Flame when tackling these more specialized heating projects.

Wide marketing opportunities are available and should be heavily investigated.

3.2.3. **OTHERS**

While being the third and 'general market area category' many viable application opportunities exist outside the product finishing and food/drink market areas.

Probably of prime interest will be the opportunity to offer CX heating systems for the production of hot water wherever it may be required. Conversion of hot water storage tanks from steam or electric heating is becoming an important area for application. The only special consideration that must be made is to the potential problem of heat exchanger pipe scaling in hard water areas. However, such scaling will be equivalent or less than that to be expected when utilizing a steam coil. Particular attention also needs to be paid to the access limitations which will exist for the installation, assembly or subsequent removal of heat exchanger pipes. (Please remember that internal flanged connections can be used with CX burner systems provided access is available for final assembly).

3.3. CUSTOMER TYPES

The following types of customer exist in all of the market areas noted.

1. The end user
2. The installation contractor
3. The consulting engineer
4. The original equipment manufacturer (OEM)
5. The gas supply utility.

3.3.1. THE END USER

A. Product Finishing

Manufacturing companies who have their own product finishing processes will provide a significant customer base for CX system sales.

Such companies usually employ Production/ Manufacturing engineering staff who are able to suggest opportunities and are therefore able and willing to work together on equipment layout design proposals.

Energy conservation and operational flexibility are seen to be important factors when considering either a change of heating system to an existing plant (a retrofit) or when specifying the design criteria that should be included within a new product finishing facility. Staff engineers will often require assistance with the preparation of a financial justification which has to be submitted to company accounting department.

Information supplied by the Power Flame Cx Calc™ will enable these running costs and capital cost assessments to be accomplished quickly and efficiently.

Metal finishing companies tend to fall into two categories depending on size and area of specialization.

1) The larger and more specialized finishing company will operate in a similar manner to the general manufacturing company described above, but with particular attention being paid to running costs which are understood to be of vital importance to their operations.

2) The smaller Finishing company is often rather more difficult to work with as they often seek the simplest and cheapest methods of heating (i.e. electric) from a capital cost viewpoint, even though the running cost arguments are quite apparent!

B. **FOOD AND DRINK AND OTHERS**

Food, drink and other process industry end users are generally well able to quantify their heating requirements but will require guidance concerning the various application areas which are potentially suited to CX burner systems due to the current domination of the industry by steam/hot water arrangements.

3.3.2. THE INSTALLATION CONTRACTORS

Some end users rely on the advice and guidance of contractors who regularly provide installation capabilities.

Installation contractors can therefore influence equipment selection decision.

The type of installation contractor can vary from the small company (sometimes with a plumbing or limited heating and ventilating industry background) to the largest specialized process heating installation operation. The range of experience with the use of CX type equipment will consequently vary accordingly.

3.3.3. **THE CONSULTING ENGINEER**

The larger type of new process engineering project may use the services of a consulting engineering company. It can be an advantage to be able to offer the Power Flame Cx Calc™ capabilities to consultants in the hope that your assistance will be remembered (and rewarded!). The disadvantage is that one often feels that you have undertaken design work which will form the basis of a specification which will be incorporated into an 'open' Bid situation.

3.3.4. **THE ORIGINAL EQUIPMENT MANUFACTURERS (OEM)**

The OEM is a very important client base. OEM's range from small companies who work almost on a 'job shop' basis for local manufacturing companies (including food and drink) to the large OEM's who specialize in certain product areas of metal finishing pretreatment plants, food industry crate washing machines and so on.

The particular attraction of the OEM sector is that once 'specified' the CX burner system would enjoy repeat orders with little further design assistance requirements. However, the competition will be fierce and OEM sales will produce the smallest profit potential. PFI is prepared to develop special commission programs and protect its Representatives who develop OEM accounts.

3.3.5. **THE GAS SUPPLY UTILITY**

Natural gas, and LPG utilities often have strong links with their customer network. It is true that some utilities take more of an interest in the equipment used by their customers than others. However the local gas utility companies should see the CX system as an opportunity to 'tie' the end user to a gas load which is not possible with central boiler systems where fuel changes frequently occur.

Enlightened gas utility companies may therefore assist with the location of suitable end user companies and may even offer facilities to send direct mailing to selected customers by SIC code using their 'billing databases'.

3.4. CX COMPETITIVE ANALYSIS

3.4.1. Introduction

For a general overview of the tank heating 'market' refer to Section 1.1 and 1.2 where the respective advantages and disadvantages of alternative tank heating methods are discussed.

Specific statements of advantages and disadvantages follow for :

a) Large diameter immersion pipe systems using atmospheric burners.

(Specific example : Eclipse '1B' and 'ES' series)

b) Large diameter immersion pipe systems using forced draft burners.

(Specific example : Eclipse 'IP' series)

c) Small diameter immersion pipe systems using forced draft burners.

(Specific example : Eclipse 'IJ' series)

d) POWER FLAME CX small diameter immersion pipe system using induced draft burners.

3.4.2. **Large Diameter Pipe Systems Using Atmospheric Burners.**

The Power Flame CX tank heating system operates into heat exchangers (or immersion pipes) which can be at 1.5" to 6.0" nominal diameter and achieve efficiencies in excess of 80%.

The large diameter tank heating systems require pipe diameters of 4.0" to 8.0" to accept similar gas input ratings and are usually designed to operate at efficiencies less than 70% due to the practical limitations associated with the installation of 'long' large diameter piping within working process tanks.

Advantages

a) Relatively inexpensive burners but immersion pipes can be expensive if constructed from materials other than mild steel.

Disadvantages

a) Immersion pipes are expensive if constructed from materials other than mild steel.

b) Often use permanent pilot flames.

c) Should only be used for small tanks and low heat input requirements (i.e. up to 300,000 BTU/h net).

d) Number of pipe bends very limited as pressure drop must be negligible.

e) Gas flame is directly visible and accessible. Not suited to modern factory safety standards.

f) Individual flues required for each burner system: large diameter and therefore expensive.

g) Immersion pipe and tank cleaning often difficult due to space occupied by heating system.

h) No computer aided design service such as Power Flame

RDS.

i) High surface temperatures at tank entry point and along initial length of immersion pipe. Can cause chemical breakdown or excessive sludge/scale formation. Also system mounting to rubber lined, plastic or glass fibre tanks is not possible.

3.4.3. **Large Diameter Pipe Systems Using Forced Draft Burners.**

Advantages

a) Relatively inexpensive burners but immersion pipes can be expensive if constructed from materials other than mild steel.

Disadvantages

Generally as listed for atmospheric burner systems except that gas flames are not directly visible or accessible and permanent pilot flames are not often used.

Also forced draft burner systems operating into large diameter pipe arrangements can have unacceptable noise levels.

3.4.4. **Small Diameter Immersion Tube Systems Using Forced Draft Burners.**

Advantages (compared with large diameter systems)

a) Immersion pipes occupy less tank space and therefore pipe and tank cleaning is easier.

b) Efficiency can be 80%+.

c) Immersion pipes are relatively inexpensive.

Advantages (compared with Power Flame CX induced draft small diameter systems)

None.

Disadvantages (compared with large bore systems)

a) Burner system is relatively expensive but -

I. Compensated by increased operating efficiency.

2. Smaller tanks can be used for process, enabling user to maximize the productivity of available floorspace.

3. Less chemicals required - can be significant.

Disadvantages (compared with Power Flame CX induced draft small diameter systems)

a) Burner system is expensive.

b) Require large combustion chamber (typically 2'9" long by 10" diameter for a 4" n.b. system) which results in the following:

1. Tank hole drillings need to be large and numerous - can be difficult especially in tanks constructed from harder grades of stainless steel.

2. Occupy valuable tank working area.

3. High surface temperature close to tank entry point - can cause chemical breakdown of excessive sludge/scale formation.

(Note : Eclipse as a result exclude certain solutions from possible application list). Also a weld is required close to burner at end of combustion chamber to attach the immersion pipe - can be under excessive thermal stress.

c) High gas and air pressures required to achieve equivalent ratings.

d) Heat exchanger piping must slope continuously downward towards exhaust outlet and provision made to drain condensate.

e) Can be prone to high resonance noise levels.

f) Number of individual immersion pipe legs restricted by gas pressure/air pressure requirements (pressure drop through heat exchanger is limited by size of integral F.D. Fan and available gas pressure).

g) Gas and air controls must be linked.

h) No computer aided design service such as Power Flame Cx Calc™.

i) Exposed HT and flame rectification connection.

3.4.5. **Small Diameter Immersion Tube System Using Induced Draft Burners** (Power Flame CX System)

<u>Advantages</u> (compared with large diameter systems)

See Section 3.4.4. above.

<u>Advantages</u> (compared with forced draft small diameter systems)

a) Burner system is less expensive.

b) No combustion chamber required - can attach to rubber lined plastic or glass fiber tanks and intrusion into tank working area is minimal.

c) Small tank hole drillings.

d) Relatively low gas pressures required. Increased combustion air fan duties do not increase gas pressure requirements.

e) No need to slope heat exchanger piping to permit draining of condensation. Suction fan will exhaust any condensation.

f) Number of individual immersion pipe legs relatively unrestricted for most tank heating applications.

g) Gas and air control can be linked to maximize efficiency.

h) Computer aided design service (Cx Calc™) which -

1. Calculates all heat losses.

2. Models anticipated performance of alternative

burner/heat exchanger arrangements.

i) Multiple burner systems can operate into a common flue. Horizontal flue runs may be used where necessary. (Consult Power Flame for specific guidance).

j) Low maintenance costs. No moving parts on burner housing.

k) Rugged construction with no exposed operating parts or electrical connections.

<u>Disadvantages</u> (compared with large diameter systems)

See Section 3.4.4. above

<u>Disadvantages</u> (compared with small diameter forced draft burner systems).

None.


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------------------------------------------------------------------
HEAT LOSS CALCULATION
---------------------
Company[Powerflame, Inc.        ]   Location[Parsons, KS.      ]
Process Line[Example            ]   Tank Ref[No. 1             ]
Quote Number[12345   ]  Date[12-15-1990]   Phone[(316) 421 0480  ]
------------------------------------------------------------------
Length[8      ]  Width[4     ]  Depth[4     ]  Liq/Depth[3.5    ]
Unit meas: [ft ]         [ft ]         [ft ]             [ft ]
------------------------------------------------------------------
Insulation[1      ] [in ]       Top Surface[AIR]
  Solution[1      ] %[......]      Oper Temp[160     ] [F]
   Make up[10      ] [gph  ]    Make up temp[50      ] [F]
------------------------------------------------------------------
  Product Weight[8000    ] [1b/h ] Prod Mat[MS       ]
  Carrier Weight[500     ] [1b/h ] Carr Mat[MS       ]
   Incoming Temp[50      ] [F]
------------------------------------------------------------------
Oth/Losses: Type[0                    ]
```

Loss[0] [bTU/h]

Warm up time[4] [hrs]
Start Temp[50] [F]

Min Amb Temp[60] [F]

RESULTS:

Tank Volume	128 CuFt	;	957 Gal(US)
Liquid Volume	112 CuFt	;	838 Gal(US)

Production Heat Losses:

Wall Losses	8,960 bTU/h
Surface Losses	39,378 bTU/h
Make Up Losses	9,163 bTU/h
Prod/Carr Losses	112,200 bTU/h
Other Losses	0 bTU/h
Net Eqm	169,701 bTU/h
Gross Eqm	212,126 bTU/h
- Rounded to	225,000 bTU/h

Warm Up Loads:

From Start Temp	768,768 bTU
Average Losses	24,169 bTU/h
Net Gas Load	216,361 bTU/h
Gross Gas Load	270,451 bTU/h
- Rounded to	275,000 bTU/h

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gure 4

HEAT EXCHANGER PIPE SIZES

PIPE DIMENSIONS (inches)		1.5	2.0	2.5	3.0	4.0	6.0
Schedule 5	O.D	1.900	2.375	2.875	3.500	4.500	6.625
	W.T	0.065	0.065	0.083	0.083	0.083	0.109
	I.D	1.770	2.245	2.709	3.334	4.334	6.407
Schedule 10	0.D	1.900	2.375	2.875	3.500	4.500	6.625
	W.T	0.109	0.109	0.120	0.120	0.120	0.134
	I.D	1.682	2.156	2.635	3.260	4.260	6.357
Schedule 40	O.D	1.900	2.375	2.875	3.500	4.500	6.625
	W.T	0.145	0.154	0.203	0.216	0.237	0.280
	I.D	1.610	2.067	2.469	3.068	4.026	6.065

O.D = Outside diameter.
W.T = Wall thickness.
I.D = Inside diameter.

NOTE: NO OTHER PIPE SIZES ARE PERMITTED.

Figure 5

HEAT EXCHANGER CALCULATION

1) Quote Number..............12345
2) Heat Input................275000 BTU/h
3) Liquid Temperature........160 degF
4) Pipe Size.................2 inNB; Sched.40; 2.067 in.I/D; 2.375 in.O/D

5)	Straights		Bends		
Ref. No.	Length(ft)	Zones	Type	Length(ft)	Zones
1	6.5	39	180 bend	.785	5
2	5.5	33	180 bend	.785	5
3	5.5	33	180 bend	.785	5
4	6.5	39			
Totals:	24	144		2.355	15

Total Length = 26.354 ft; Total Zones 159
Total surface Area = 16.387 sq. ft.

Firing Intensity = 81,994 BTU/h.sq.in.

Heat Flux - Average = 13,470 Maximum = 37,621 BTU/h.sq.ft.

Heat Release = 80.272 %   Heat to Liquid = 220,749 BTU/h

Flue Gas Temp. = 435 degF

==

PRESSURE DROP CALCULATION

Volumetric Flow = 3877 std.cu.ft./h   (64 scfm)

STRAIGHTS
Pressure Drop Factor = .085

TOTAL PRESS. DROP FACTOR FOR STRAIGHTS = 2.039

BENDS

No.	Type	Cold VHL	Hot Factor	Hot VHL	Hot Loss
1	180 bend	0.700	3.105	2.173	1.062
2	180 bend	0.700	2.367	1.656	0.809
3	180 bend	0.700	1.885	1.319	0.644

Total Pressure Drop Factor for Bends = 2.515

Total Pressure Drop Factor for Heat Exchanger = 4.554

Figure 10