LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Thank you for selecting Westland Environmental Services Inc. (Westland) to provide you with a reliable, proven and cost-effective system to manage your waste in an environmentally sound manner. This manual has been prepared to allow you to operate and maintain the system safely and efficiently, thereby ensuring its proper operation and continued use for a long period of time.

It also contains information on the combustion process. We believe that understanding the basic principles would make you more knowledgeable, and hence a better operator. Table 1 outlines the contents of this manual, of which Sections 3 and 4 are the required minimum reading.

Table 1 Organization of Manual

Section Number	**Title** Brief Description
2	**Principles of waste incineration** What incineration or combustion process is, why waste is incinerated and the components of a waste, including heating value, and how waste properties affect incinerator operation.
3	**System Description** The components, their designs and their functions are described
4	**Operation and Maintenance** How to operate and maintain the system, including safety equipment to be used.
5	**Warranty** Terms of the warranty

2 PRINCIPLES OF WASTE INCINERATION

2.1 Combustion

Combustion, burning, incineration, and thermal oxidation all denote the same process, which is the reaction of a "combustible" matter with oxygen that occurs at temperatures higher than the ignition temperature [1] of that matter. The reaction is exothermic, meaning that it generates heat in the form of hot gases.

In the case of waste, it may also contain non-combustible matter which does not react with oxygen. In waste incineration, the non-combustible component ends up as ash and a small portion of it is also present in the hot gas in the form of particulate matter or dust.

[1] Below the ignition temperature combustion does not take place. Consider, for example, gasoline or wood: it has to be "ignited" for combustion to take place. That is, the temperature in some portion of the matter must be brought up to the ignition temperature for combustion to start.

Figure 1 shows schematically the process of waste incineration. The oxygen used comes from air, which contains 21% of oxygen by volume, and the hot gas is typically referred to as flue gas or stack gas.

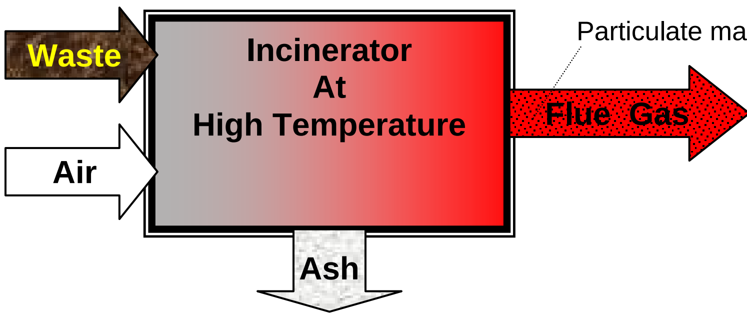

Figure 1 Schematic Diagram of Incineration Process

2.2 Why incinerate waste?

The main purpose is to reduce the mass and volume for final disposal. Another important reason, since the waste may contain pathogenic, infectious or toxic materials, is to "detoxify" it by the high temperature process. In remote areas where wildlife is present, scavenging can be prevented by incineration.

In some cases, typically in large-scale operation, incineration is used to recover the energy contained in the waste in the form of electricity, steam, hot fluids or hot air. In other cases, valuable materials can be recovered from the ash, or the ash as a whole can be used for soil amendment or as a construction material.

2.3 Waste components

There are different ways of characterizing waste, depending on the purpose for doing it. Here, it is sufficient to characterize the components as follows: [2]

A. Water is an important component because in incineration it has to be evaporated first, which requires a lot of energy, [3] which in turn, has the effect of lowering the temperature of the flue gas.

B. Combustible is the component that reacts with oxygen and releases heat in the process. [4] The higher the combustible content in the waste, the more air per kg of waste is needed for incineration.

This component can be further classified as:

---

[2] This is referred to as proximate analysis. Another method is elemental analysis, which produces the elemental composition (C, H, O, N, S, Cl …) of the waste.

[3] It takes ~ 2.3 MJ (2200 BTU or 90 cc of propane or 60 cc of diesel) to evaporate 1 L or 1 kg of water. This is referred to as the latent heat of evaporation.

[4] The term "organic" is also used, which is strictly incorrect in that some "inorganic" elements or compounds are combustible, such as carbon, sulphur, ammonia and carbon monoxide.

(i) **Volatile**, which is released to the gas phase when the combustible matter is heated without the presence of oxygen, and

(ii) **Fixed carbon** which remains in the solid waste after the volatile has been released. This is often referred to as charcoal.

C. Non-combustible is the component that does not react with oxygen. [5] As previously mentioned, this forms ash, and some of it is entrained in the flue gas in the form of particulate matter or dust. The higher the non-combustible content in the waste, the less quantity of waste that can be incinerated without removing ash from the combustion chamber. Note also if the waste contains metals, such as lead and cadmium, these metals will be present in the ash as well as in the flue gas, in the form of particulate matter and vapour.

2.4 Heating Value

Heating value, calorific value and heat of combustion are synonyms that quantify the heat released by the combustible component in the waste upon complete combustion. An understanding of the concept can be gained from the hypothetical processes shown in Figure 2.

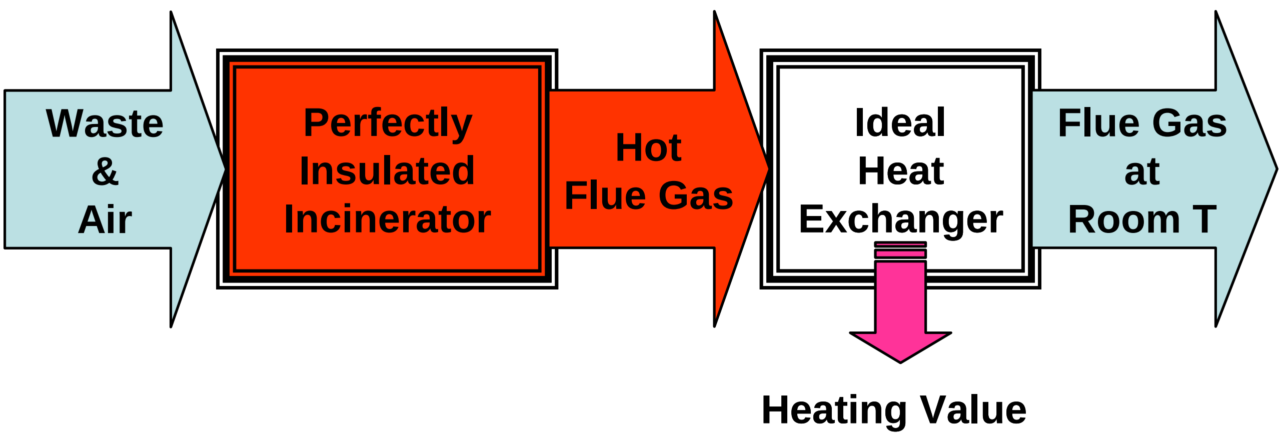

Figure 2 The Concept of Heating Value

A measured mass of dry waste and a sufficient amount of oxygen, at room temperature, are ignited, and the resulting hot flue gas is passed through a heat exchanger, where heat is extracted until the flue gas is brought back to room temperature. Let M be the mass (kg) of the dry waste fed, and H (MJ) the heat extracted from the heat exchanger. The heating value of the dry waste is H/M (MJ/kg).

2.5 Different Expressions for Heating Value

Two different values are reported in the literature (a) “high” or “gross”, and (b) “low” or “net”. The former corresponds to the case where the moisture in the flue gas is

[5] The terms “ash” and “inorganic” are also used. Note that the latter is inaccurate as explained previously.

condensed, and hence the high or gross heating value *includes* the latent heat of evaporation of the water formed in combustion (see Footnote 3). The latter excludes the latent heat evaporation. The low or net heating value thus represents the maximum available energy that can be recovered from the flue gas without condensation.

To be noted also is the basis on which the heating value is expressed, which can be (a) as fired, (b) dry basis or (c) ash free. The distinction is illustrated in Figure 3. An understanding of the different bases can be gained by noting that heating value is a property of only the combustible component in the waste. Water and the non-combustible component simply "dilute" the heating value. In terms of incinerator operation, the relevant basis is "as fired".

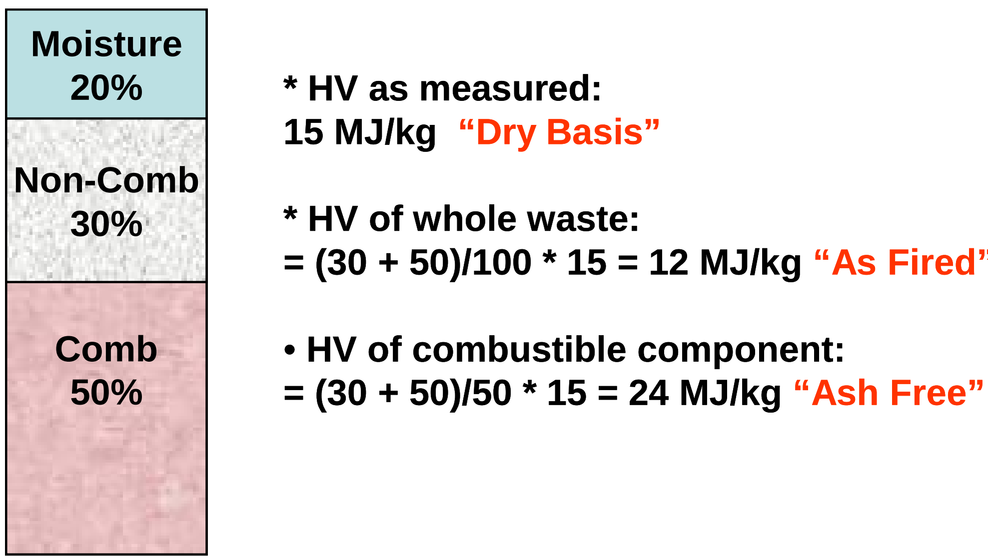

Figure 3 Different Bases for Expressing Heating Value (HV)

2.6 Examples of waste characteristics

Proximate compositions and heating values of commonly found wastes are given in Table 2.

Table 2 Classification and Properties of Common Wastes

Type*	Description	Components	Weight %			MJ/kg
			Moist	Comb	Non-C	HHV (A/F)
0	Trash	Paper, cardboard, cartons wood boxes and combustible floor sweepings from commercial and industrial activities. Up to 10% by weight of plastic bags, coated paper, laminated paper, treated corrugated cardboard, oily rags and plastic or rubber scraps.	10%	85%	5%	19.7
I	Rubbish	Trash + Type 3 (up to 20%)	25%	65%	10%	15
2	Refuse	Rubbish and Garbage	50%	43%	7%	10
3	Garbage	Animal and vegetable wastes, restaurants, hotels, markets, institutional, commercial and club sources	70%	25%	5%	5.8
4	Animal/ Pathological	Carcasses, organs, hospital and laboratory, abattoir, animal pound, veterinary sources	85	10	5	2.3

Notes:
Moist = moisture, Comb = Combustible, Non-C = Non-combustible, HHV = High Heating Value, A/F = As Fired
* In some cases Roman numerals are used. That is Types 0, I, II, III and IV

2.7 Incinerator Capacity and Load Size

Incinerator capacity is dependent on waste composition. For a given mass, the amount of air required for complete combustion increases with increasing heating value. Hence, for a given incinerator which delivers a given flow rate of combustion air, its capacity for waste burning in kg/h decreases with increasing heating value of the waste, or to put it in opposite way, it, increases with decreasing heating value.

Another important consideration is the size of the batch loaded to the incinerator. The higher the heating value, the smaller (lighter) the load should be. Otherwise, the insufficient amount of air will generate black smoke.

Unfortunately, waste composition is usually not known. Nevertheless there may be indications on the basis of the components present. To assist in getting a qualitative estimate of the heating value of a batch of waste, the heating values of common "generic" waste components are shown in Table 3.

Table 3 High Heating Values (Approximate) of Common Waste Components

Component	MJ/kg A/F *	Component	MJ/kg A/F *
Kerosene, Diesel …	44	Leather	16
Plastics	46	Wax paraffin	44
Rubber, Latex	23	Rags (linen, cotton)	17
Wood	18	Animal fats	39
Paper	17	Citrus rinds	4
Agricultural waste	17	Linoleum	25

* A/F: As Fired

Another important waste component is the volatile content in the waste. Table 4 shows the proximate components of various materials and wastes.

In general, this component is responsible for smoke generation. Therefore, as in the case with heating value, the higher the volatile content, the smaller the load that should be charged to the incinerator.

Table 4 Proximate Composition of Various Materials

Material	Volatile	Moisture	FC	Ash	FC/V
	%wt	%wt	%wt	%wt	-
Coal (bit.)	30	5	45	20	1.5
Peat	65	7	20	8	0.3
Wood	85	6	8	1	0.1
Paper	75	4	11	10	0.15
Sewage sludge	30	5	20	45	0.66
MSW	33	40	7	20	0.21
RDF	60	20	8	12	0.13
PDF	73	1	3	13	0.04
TDF	65	2	30	3	0.46
PE,PP,PS	100	0	0	0	0
Plastics + Colour	98	0	0	2	0
PVC	93	0	7	0	0.08

Notes: **FC** : Fixed Carbon; **FC/V**: Ratio of Fixed Carbon to Volatile
(bit: bituminous; MSW: municipal solid waste; RDF: refuse derived fuel; PDF: packaging DF: TDF: Tire DF; PE: polyethylene; PP: polypropylene; PS: polystyrene; PVC: polyvinyl chloride)

3 SYSTEM DESCRIPTION

3.1 Nomenclature for Different Models

This series of incinerator is designated by

CY-(nn)-CA-(x)-O

where **nn :** a number denoting the nominal capacity of the incinerator in kg/h;
x : a letter denoting the auxiliary fuel used, denoted as follows:
D for diesel; **P** for propane and **N** for natural gas

For example, **CY-100-CA-D-O** denotes a 100 kg/h unit using diesel as auxiliary fuel.

3.2 Overview [6]

Regardless of the model of your incinerator, the main components are similar. Figure 4 shows a schematic diagram of the incineration system. It consists of a **Primary Chamber** and a **Secondary Chamber**, which are connected by a "flame-port". Combustion air to the

[6] **Bolded words** correspond to those used in Figure 4

primary chamber is delivered by the **under-fire air blower,** and to the fame-port by the **flame-port air blower**. **Aux**iliary **burners** are provided for start-up and to maintain the minimum temperatures set in the primary and secondary chambers.

Thermocouples are used to measure the temperatures in the primary and secondary chambers, the outputs of which are used by on-off **Omron controllers** which regulate the operation of the auxiliary burners.

The oxygen concentration in the secondary chamber is measured by an **oxygen probe**, the output of which is used by a programmable logic controller (**PLC)** to regulate the flows of the under-fire and flame-port air. This control minimizes the occurrence of black smoke generation, and will ensure that black smoke is not generated provided the size of the waste load is not too large. The PLC also informs the operator when the combustion of a batch has been completed, and hence the next batch can be charged.

Waste is charged manually and intermittently via the **waste charging door (1),** and ash is removed manually and batch-wise after previous operation via the **ash removal door (2).** This door is also used to rake the waste in the primary chamber after several loads have been charged, which is necessary to expose the fixed carbon component in the waste to the under-fire air.

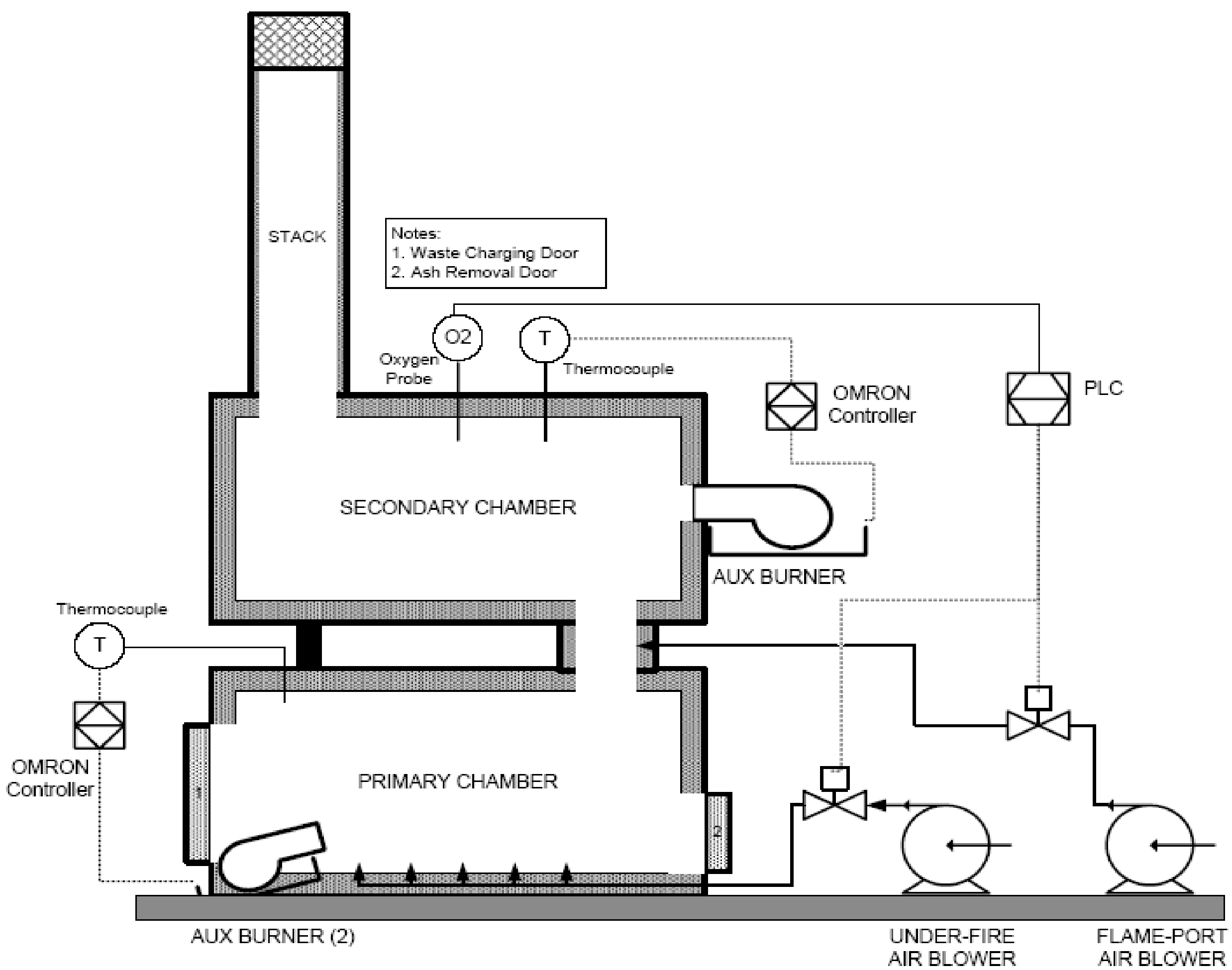

Figure 4 Schematic of the Incineration System

3.3 Description of system components

For convenience, the system has been grouped into sections, as shown in Figure 5. In each section, the components are shown in subsequent photographs. Each component is coded with a number and a prefix corresponding to the section to which it belongs. *These codes are unique and will be used in later sections on operation, maintenance and trouble shooting.* The following Tables contain all the components in the system, their codes and brief descriptions of their functions.

Information on components that are not manufactured in-house, such as blowers and burners, is given in the accompanying binder. Please consult the corresponding manuals for details of operation and maintenance.

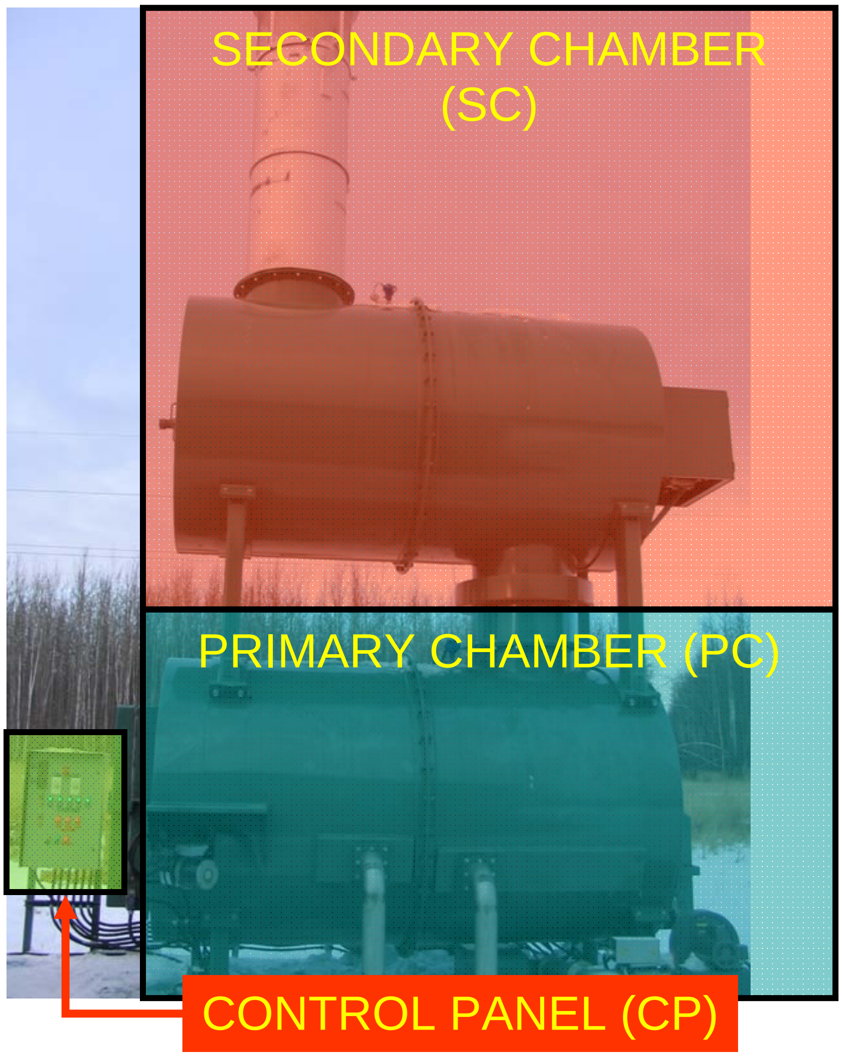

Figure 5 Overall View showing the Sections

3.4 Primary Chamber Section

The components are listed in Table 5, and the photographs are shown in Figure 6 to Figure 8.

Table 5 Components in the Primary Chamber Section

Code	Component	Description	Function
PC1	Primary Chamber	In-house made. Inside Vol: 2.8 m^3 Refractory: 10 cm; Insulation 7.5 cm	Pyrolysis and gasification Combustion of fixed carbon
PC2	Charge Door	In-house made. Door opening: 89 cm x 69 cm	Load waste to primary chamber
PC3	Ash Door	In-house made. Door opening: 48 cm x 38 cm	Raking and ash removal
PC4a	Contact Switch	SquareD ZCKJ1H7	Turn off primary chamber burner when charge door is opened
PC4b	Same as PC4a for ash door		
PC5a	Auxiliary Burner	Becket WIC-201; 700,000 Btu/h; 5 USG/h	Start-up and maintains a minimum temperature
PC5b	Same as PC5a		
PC6	Under-fire Air Blower	4C 108 Dayton; 1 HP; 3600 rpm	Combustion air supply to primary chamber
PC7	Butterfly Valve	V51E-1075	Regulate under-fire air flow
PC8	Actuator	Neptronics BBMF 2000A	Adjust position of butterfly valve
PC9	Under-fire Plenum	In-house made	Distribute under-fire air in primary chamber
PC10	Thermocouple	Wika (sheathed)	Measure temperature in primary chamber

3.5 Secondary Chamber Section

The components are listed in Table 6, and the photographs are shown in Figure 6 to Figure 8.

Table 6 Components in the Secondary Chamber Section

Code	Component	Description	Function
SC1	Secondary Chamber	In-house made. Inside Vol: 2.8 $m^{3,}$ Refractory: 10 cm; Insulation 7.5 cm	Combustion of combustible gases and soot generated in primary chamber
SC2	Flame-port Plenum	In-house made.	Mixing of combustible gases and flame-port air
SC3	Flame-port Air Blower	4C 108 Dayton; 1 HP; 3600 rpm	Combustion air supply to flame-port plenum
SC4	Butterfly Valve	V51E-1075	Regulate under-fire air flow
SC5	Actuator	Neptronics BBMF 2000A	Adjust position of butterfly valve
SC6	Thermocouple	Wika (sheathed)	Measure temperature in secondary chamber
SC7	Oxygen Probe	DL-300 Oxytrol	Measure oxygen concentration in secondary chamber
SC8	Auxiliary Burner	Becket WIC-301; 1.6 million Btu/h; 12 USG/h	Start-up and maintain minimum set temperature
SC9	Sight glass	In-house made	Observation of secondary chamber
SC10	Stack	In-house made	Dispersal of flue gas

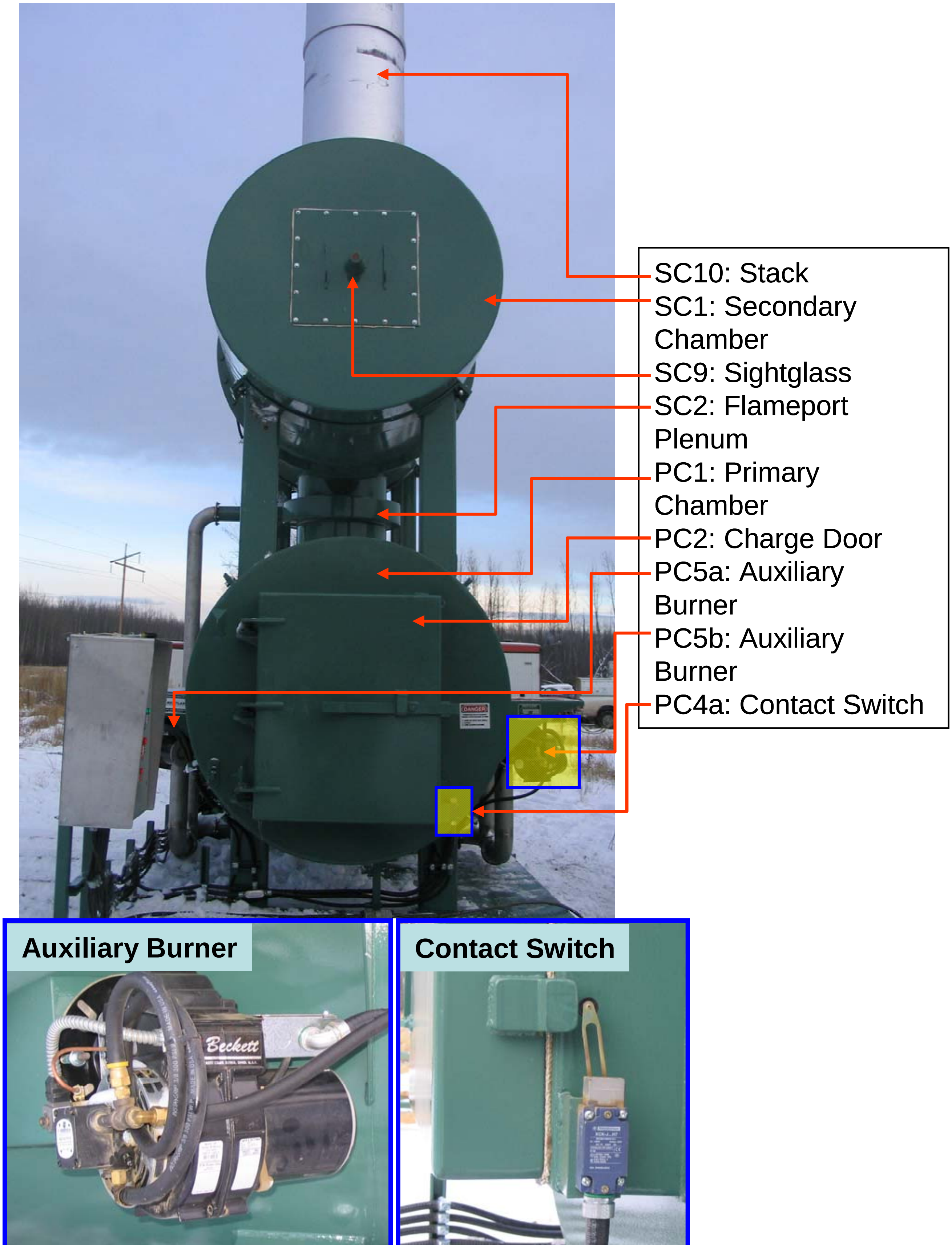

Figure 6 Components in the Primary and Secondary Chamber Sections (1)

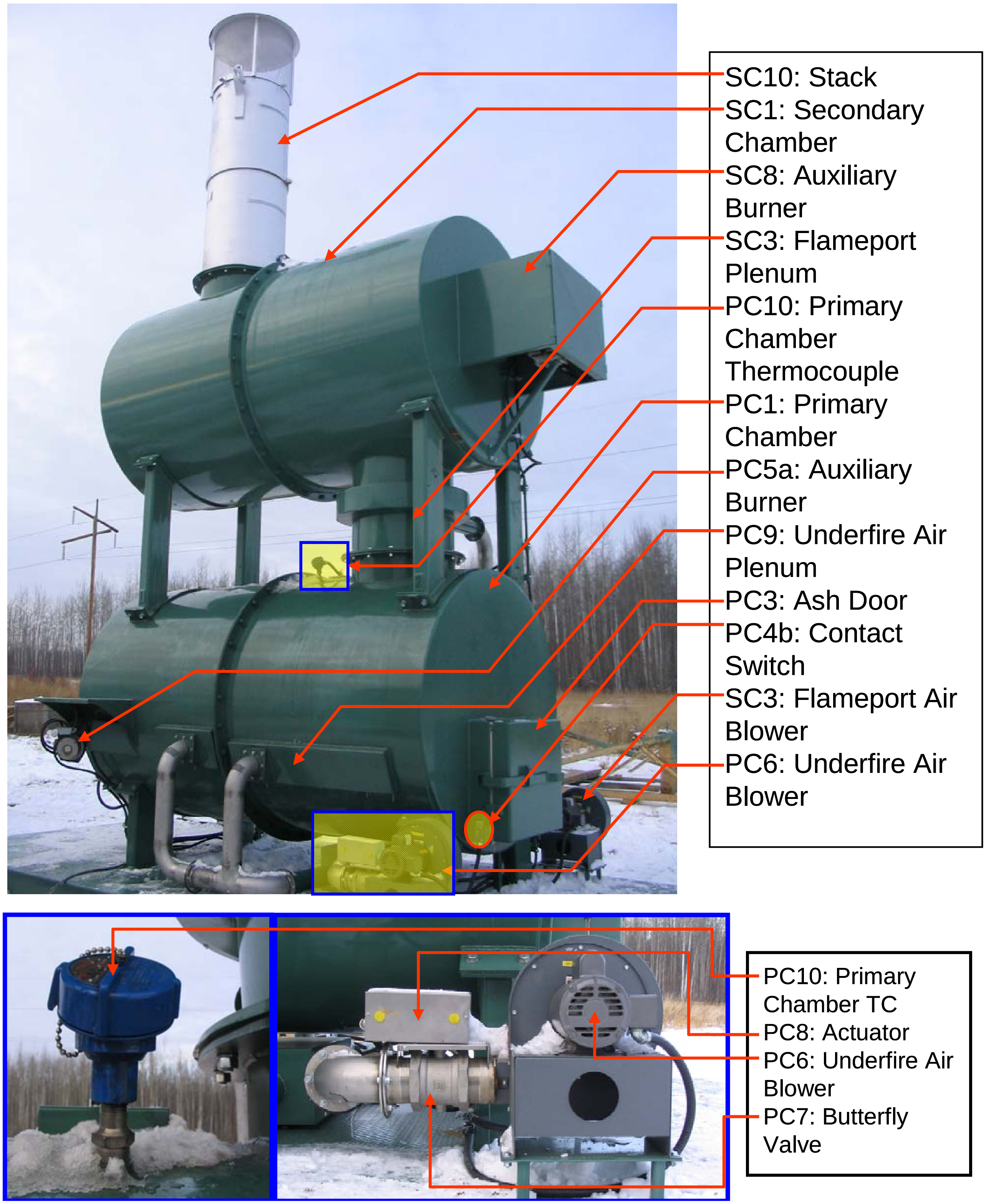

Figure 7 Components in the Primary and Secondary Chamber Sections (2)

Figure 8 Components in the Primary and Secondary Chamber Sections (3)

3.6 Control Panel Section

The components are listed in Table 7. Figure 9 shows a photograph of the whole control panel, which has been divided into sub-sections marked A, B, C, D and E, each of which is shown in Figure 10 to Figure 12

Table 7 Components in the Control Panel Section

Code	Label	Function
Sub-Section A: Indicating Lights (ON_OFF). Figure 10		
CP1	Burner Blower #1, #2 and #3	#1 and #2: Motors for burners in primary chamber: PC5a and PC5b #3: Motor for burner in secondary chamber: SC8
	Under-fire Blower Flame-port Blower	Under-fire air blower: PC6 Fame –port air blower SC3
CP2	Primary Chamber Primary Chamber Secondary Chamber	Flames in burners indicated in the labels
Sub-Sections B and C: Main Controller and Controllers for Burners and Blowers. Figure 11		
CP3	E-STOP	Emergency stop: ▪ Push to activate: disconnects main power ▪ Twist right to connect main power
CP4	Blower Timer Burner Timer	Turn to connect power to blowers and burners for the specified time periods
CP5	Blowers Start and Stop Burners Start and Stop	Turn ON and OFF all blowers or burners while time has not expired in Timers PC4 (Note: These buttons are inactive when the timers are OFF, that is, at zero time)
Sub-Section D: Omron Temperature Controllers and Indicators. Figure 12		
CP6	Primary Chamber T.C. Secondary Chamber T.C.	Temperature displays and control of minimum temperatures in primary and secondary chambers by setting adjustable set points (OMRON E5CN)
Sub-Section E: PLC Indicating Lights and Control Button. Figure 12		
CP7	Red Indicating Light (Marked 3 in photo)	▪ FLASHING: PLC is NOT ready since temperature is too low for oxygen probe ▪ ON: PLC is ready
CP8	Green Indicating Light (Marked 2)	▪ ON: Combustion from previous batch is complete: READY to load a new batch ▪ OFF: Combustion is taking place. Do NOT load. Wait.
CP9	Green Button (Marked 1)	PRESS *immediately* after a loading: Activates PLC control

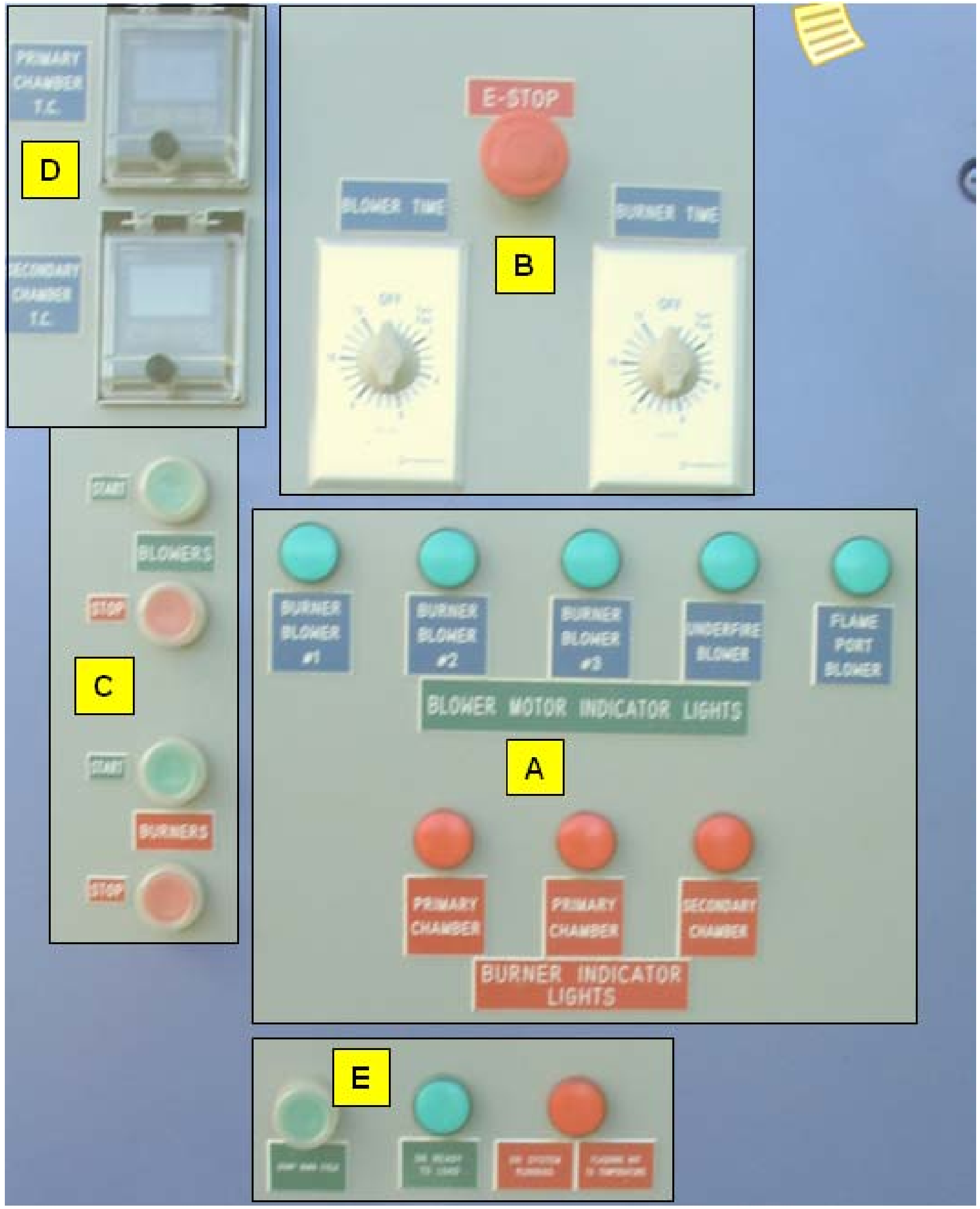

Figure 9 Overview of Control Panel, showing the Different Sections

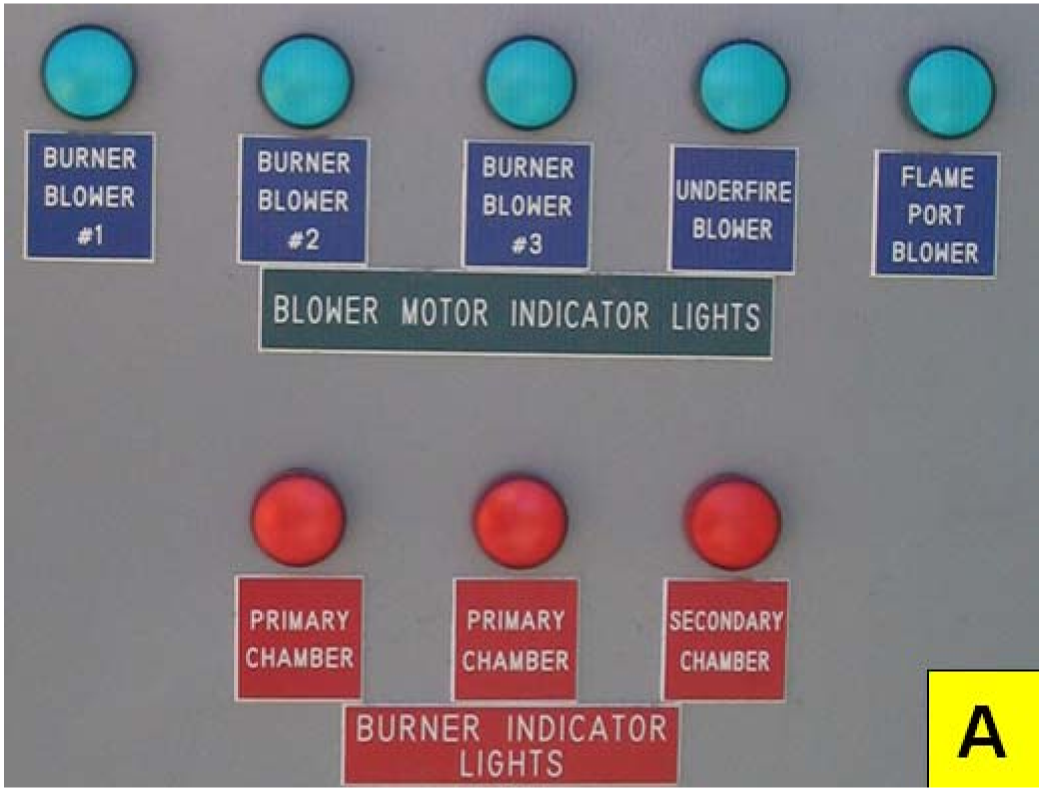

Figure 10 Sub-Section A: Indicating Lights
[CP1 and CP2 in Table 7]

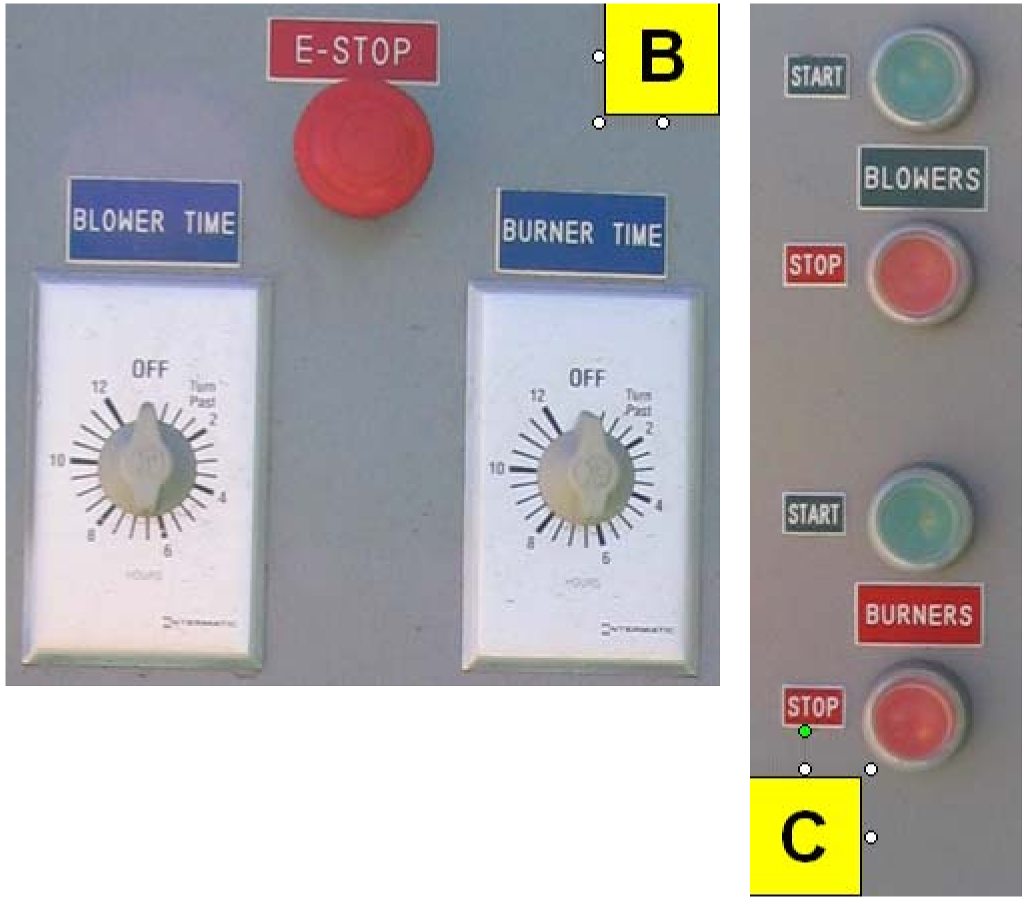

Figure 11 Sub-Sections B and C: Controllers for Burners and Blowers
[CP3, CP4 and CP5 in Table 7]