SUCCESSFUL FIELD PERFORMANCE OF A HEATSET WEB OFFSET ENVIRONMENTALLY COMPLIANT DRYER WITHOUT REMOTE INCINERATION

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Abstract: Previous drying systems in heatset web offset required the use of a remote incinerator. The equipment discussed here uses products of combustion of incinerated ink oils as the heat source for the drying process. This is accomplished with only a single burner located within the dryer. Conventional technology uses large remotely located incinerators having separate combustion chambers, burners, fans, dampers, and heat exchangers.

Results of dynamic performance tests of the new dryer in a production environment are discussed and include quantification of exhaust gas constituents and fuel usage as compared to conventional equipment. Operating characteristics and system heat and mass balance are also discussed.

Background

Current day heatset inks must be dried after application by heating the paper web to 120 to 180°C (248 to 356°F) to vaporize the hydrocarbon ink oils. This is normally accomplished in a gas fired air flotation dryer with supply air temperatures between 130 to 260°C (266 to 500°F).

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Organic vapors thus formed are then exhausted from the dryer where they are then treated by one of several available types of remotely located pollution control (PC) devices to remove the organics from the air stream or incinerate them to carbon dioxide and water. All of these existing available PC devices have various limitations and disadvantages which can include several of the following: long warm-up time, large size, expensive installation requirements, energy consumptive idle modes, insufficient clean-up, excessive energy consumption, expensive maintenance, overtemping at higher LFL levels, expensive catalyst replacement due to poisoning from phosphorus or silica, thermal degradation at required operating temperatures, inconvenient location, disposal of captured oil, and leaky dampers where exhaust fume can completely bypass the pollution control device.

Introduction

Refer to Appendix A for definition of abbreviations.

A unique heatset web offset dryer designed and constructed by TEC Systems, was installed at Wagners Printers in Davenport, Iowa and was started up October 12, 1988. This dryer has a single zone, is 5.5 meters (18 feet) long, and is capable of incinerating in excess of 99% of all vaporized ink oil and volatile organic chemicals (VOC's) within the dryer itself at 870°C (1598°F) so that no external remote pollution control equipment is required other than the exhaust stack to the roof. Hydrocarbon in the exhaust is below 10 ppmv as C1 and carbon monoxide is below 30 ppmv. Exhaust rates and fuel consumption are minimized by monitoring LFL levels.

An isometric cutaway drawing of the dryer is shown in Figure 1 and a flow schematic is shown in Figure 2.

The printing press is a five (5) unit Miller 66, 67.3 centimeters (26.5 inch) with maximum web speed of 45,000 impressions per hour or 338 meters (1,109 feet) per minute.

The original burner was a modified raw gas burner which was adapted for 50 to 70% stoichiometric premix combustion air. This burner often flamed out during rapid cold start-up due to low oxygen levels and was ultimately replaced with a 100% stoichiometric combustion air nozzle mix line burner.

Temperature control is achieved through a patented means of modulating fan speeds and high temperature (products of combustion) dampers. Upon oxidizing the hydrocarbons in the exhaust air stream, a portion of the clean air is recirculated within the dryer providing the heat for drying the print. Excess heat is exhausted to secondary recovery devices. This approach benefits the total thermal dynamics of the system by eliminating losses which occur in heat exchange devices. Additionally, energy is no longer lost during printing press idle times since the dryer is turned off similar to conventional systems. Dryers using conventional pollution control require operation of the pollution equipment during press idle periods because of the thermal mass of heat exchangers.

Fuel efficiency and safety of the SUMMIT is enhanced through the use of a direct dryer mount LFL monitoring system (the "Regulator") which is new and contains automatic calibration. The flame cell block components are easy to access. The unit has an orifice and aspirator spool for easy removal and maintenance.

Objectives

There were several objectives to this study. First was to determine if the drying portion of the dryer performed acceptably. This included evaluation of attainable web speed, warm-up time, down time and overall reliability as

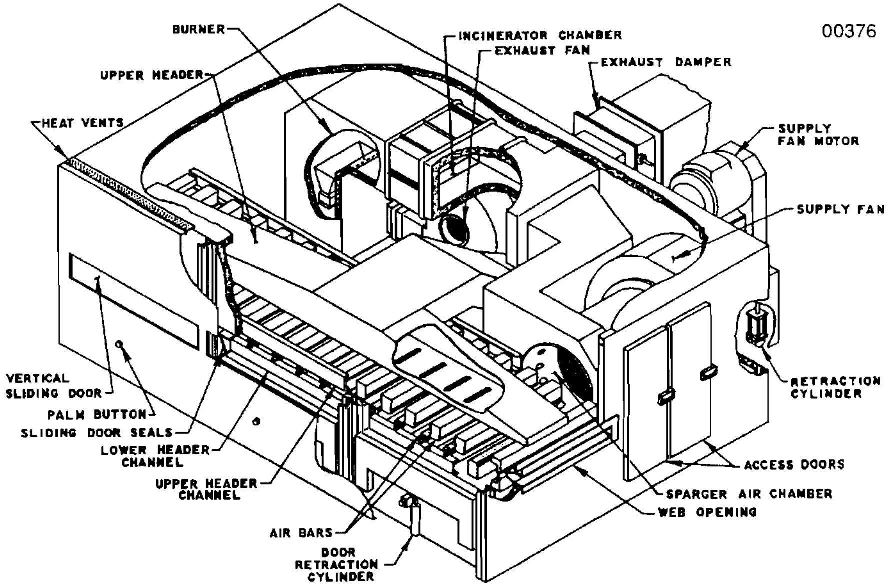


Figure 1. SUMMIT™ (patent pending)

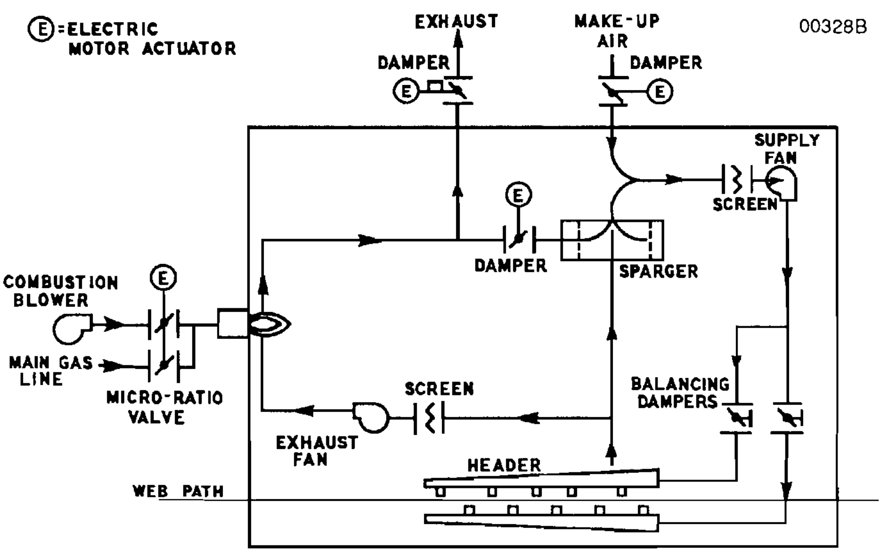


Figure 2. SUMMIT™ Air Flow Diagram

related to drying capability. Second was to verify computer projections based on a computer program that calculated ink drying rate, fuel consumption, heat and mass balance, as well as concentrations and distribution of nitrogen, oxygen, water vapor, carbon dioxide, and solvent vapor. Third was to verify that acceptable exhaust levels of hydrocabon and carbon monoxide were obtained. Fourth was to determine if exhaust rates could be controlled and minimized so that fuel consumption would be acceptably low. Fifth was to determine if a preprogrammed start-up routine could lead to rapid start-up without exfiltration (belching) at the web slots but allow reduced exhaust during steady-state operation.

Experimental

Dryer and pollution control performance were monitored continuously during actual production runs. Data included monitoring of natural gas consumption, oxygen, carbon dioxide, carbon monoxide, hydrocarbon residuals, web speed, web weight, ink consumption rate, supply air temperatures, combustion chamber temperatures, combustion chamber pressures, warm-up times, damper positions, exhaust rates, exhaust fan speed, skin temperatures, and percent of lower flammability limit (LFL) measurements. Instruments used were as follows:

The Oxygen analyzer was a Beckman Model 755A Paramagnetic, the Carbon Monoxide analyzer was a Beckman Model 864 Nondispersive Infrared (NDIR), the Carbon Dioxide analyzer was a Beckman Model 864 Nondispersive Infrared (NDIR), the Hydrocabon analyzer was a Bernath Atomic Model 3005 Flame Ionization Detector (FID) or Ratfisch Model RS55, the LFL monitor/controller was a Control Instruments Model FFA RTD Hydrogen Flame (specially designed and modified for TEC Systems), and the Computer/Recorder was a Compaq Portable III Model.

Results

. First Objective - Drying Performance

With the original burner system, warm up times were slower than desired by Wagners Printers. Acceptable web temperatures were not obtained rapidly enough due to burner flame outs caused by low oxygen levels during cold start ups. Oxygen dropped to as low as 12 to 14% within about three minutes after start up and did not start recovering again for another four to five minutes. Ultimately, the original burner was replaced with a nozzle mix burner and acceptable start ups were achieved.

Actual ink drying performance was equivalent to conventional dryers. Supply air temperatures at steady-state operation were ± 1.5 C° (± 3 F°) and web exit temperatures were ± 0.5 C° (± 1 F°).

In general, it was found that the highest skin temperatures were found at the points where structural steel bridged the gap between the internal cladding and the external skin. External skin temperatures near the combustion chamber itself did not appear to increase the external skin temperatures by more than 10 C° (18 F°) when the combustion chamber operated at 871°C (1600°F).

. Second Objective - Verify Computer Projections.

The second objective of the Wagners study was to determine if the actual conditions observed agreed with the computer generated estimates. Table 1B shows two typical actual and computer projected operating conditions and fuel consumptions for the single zone SUMMIT.

. Third Objective - Exhaust Clean-up

Tables 2 and 3 contain carbon monoxide and hydrocarbon clean-up levels.

. Fourth Objective - Fuel Consumption

Data shown in Tables 1A and 1B show fuel consumption with original burner in place. Table 3 contains data with new burner.

. Fifth Objective - Preprogrammed Start-up

Programmed variables could be adjusted in the field to optimize start-up conditions.

Discussion

First Objective - Evaluate Drying Performance

Except for the slower than desired start-ups when the original burner was in place, the dryer appeared to dry the web in a manner equivalent to current day conventional air flotation dryers. Overtemping of the web was sometimes a problem if the unit was run at 1600°F when the heat load was small. The purchased high temperature damper leaked enough hot combustion products back into the dryer so that in conjunction with heat generated from the recirculation fans and heat conducted thru the combustion chamber walls, excessive temperatures were reached. A new "low leak" damper has been designed and built by TEC to eliminate this problem. It is scheduled for installation at Wagners Printers in early April 1990.

Second Objective - Computer Projections

Typical observed operating data is listed in Table 1B along with expected values projected by the SUMMIT computer program. Given the complexity of the system, the agreement is excellent except for the combustion chamber temperature. The reason for this discrepancy is that the computer generates the temperature just downstream of the burner whereas the thermocouple controller - from which the actual operating temperature is taken - is located farther downstream closer to the exhaust damper.

Table 1A

WAGNERS PRINTERS - "SUMMIT"

Production Date of November 30, 1988
Paper basis weight: 53.3 gm/m² (36 lb/ream)
Web width: 58.4 cm (23 in)
Web speed: 338 m/min (1,109 ft/min)
Ink coverage: 0.50 gm/m² (0.34 lb/ream)

Time of Day	Exhaust Stack Nm^3/hr (SCFM)	Combustion Chamber Pressure mm Hg (in W.C.)	Exhaust Damper (% Open)	% of LFL	Actual Fuel Consumption * 1000 Net kJ/hr (Btu/hr)	Actual Fuel Consumption * 1000 Gross kJ/hr (Btu/hr)	Oxygen (%) Dry	Oxygen (%) Actual
09:25	1,075 (682)	1.87 (1.0)	100	1-4	1,618 (1,534)	1,798 (1,704)	18.9	17.9
09:53	580 (368)	1.87 (1.0)	37	4	826 (783)	918 (870)	18.0	16.3

Table 1B (Reference Table 1A)

	Expected		Observed	
09:25				
Fuel (Gross kJ/hr)	1,904,000		1,798,000	
Percent Oxygen Before Burner	18.1		17.9	
Percent Oxygen After Burner	10.5		10.6	
Percent Carbon Dioxide Before Burner	0.9		0.8	
Percent Carbon Dioxide After Burner	4.5		4.5	
Combustion Chamber Temperature (°C)	1,024	(1,875°F)	843	(1,550°F)
Percent of Lower Flammability Limit	5		2-4	
Supply Air Temperature (°C)	181	(358°F)	198	(388°F)
Web Temperature (°C)	166	(330°F)	160	(320°F)
09:53				
Fuel (Gross kJ/hr)	919,000		918,000	
Percent Oxygen Before Burner	16.7		16.3	
Percent Oxygen After Burner	10.0		10.2	
Percent Carbon Dioxide Before Burner	1.2		1.1	
Percent Carbon Dioxide After Burner	4.5		4.4	
Combustion Chamber Temperature (°C)	958	(1,756°F)	843	(1,550°F)
Percent of Lower Flammability Limit	9		4	
Supply Air Temperature (°C)	182	(360°F)	193	(380°F)
Web Temperature (°C)	166	(330°F)	160	(320°F)

Table 2

Run Date: December, 1988

Combustion Chamber Temperature °C	(°F)	% LFL	PPM Hydrocarbon (as Propane)	Hydrocarbon At Stack (ppmv as Propane)	Destruction Efficiency (%)
871	(1600)	18.0	3776	2.5	99.9 (No CO)
816	(1500)	18.0	3776	4.6	99.8
760	(1400)	18.0	3776	4.8	99.8 (Some CO)
704	(1300)	18.0	3776	4.8	99.8 (Much CO)
649	(1200)	18.0	3776	8.0	99.7

Under these conditions the burner was at minimum fire. During this timeframe, the press was operating at 30,000 IPH.

Table 3

Run Date: May 24, 1989
Wagners Printers - Davenport, IA

1% LFL = 208 ppmv as propane
2% LFL = 416 ppmv

30,000 IPH = 225.2 m/min (739 ft/min)
Combustion Chamber Pressure = 5.61 mm Hg (3.0 inch)
Exhaust Damper = 100% Open
LFL = 2 = 416 ppmv as propane

Web Weight = 81.4 gm/m^2 (55 lb/ream)
Web Width = 62.2 cm (24.5 inch)
Fan Speed = 42 Hz

Time	Temperature °C (°F)	CO (ppm)	HC (ppmv as Propane)	Conversion
18:40	760 (1400)	<23	1 - 2	99.6 - 99.8%
18:49	704 (1300)	<25	6 - 10	97.6 - 98.6%
18:55	677 (1250)	<25	16 - 17	95.9 - 96.2%
18:58	649 (1200)	300 - 500	28 - 37	91.1 - 93.3%
19:03	621 (1150)	1000 - 1250	60	85.4%
19:24	427 (800)	<25	390	

< means less than

Note: Fuel consumption is 30% higher with this burner than with previous burner.

Typically, the temperature drops about 100 to 200 F° as heat is lost through the combustion chamber walls before the operating thermocouple is reached. This "lost" heat, which usually amounts to about 105,500 kJ/hr (100,000 Btu/hr), goes directly back into the dryer so it is not wasted.

Measurement of the carbon dioxide and oxygen levels before and after the burner can be used to calculate the peak temperature attained in the vicinity of the burner. Actual exhaust flow rates are also calculated using carbon dioxide

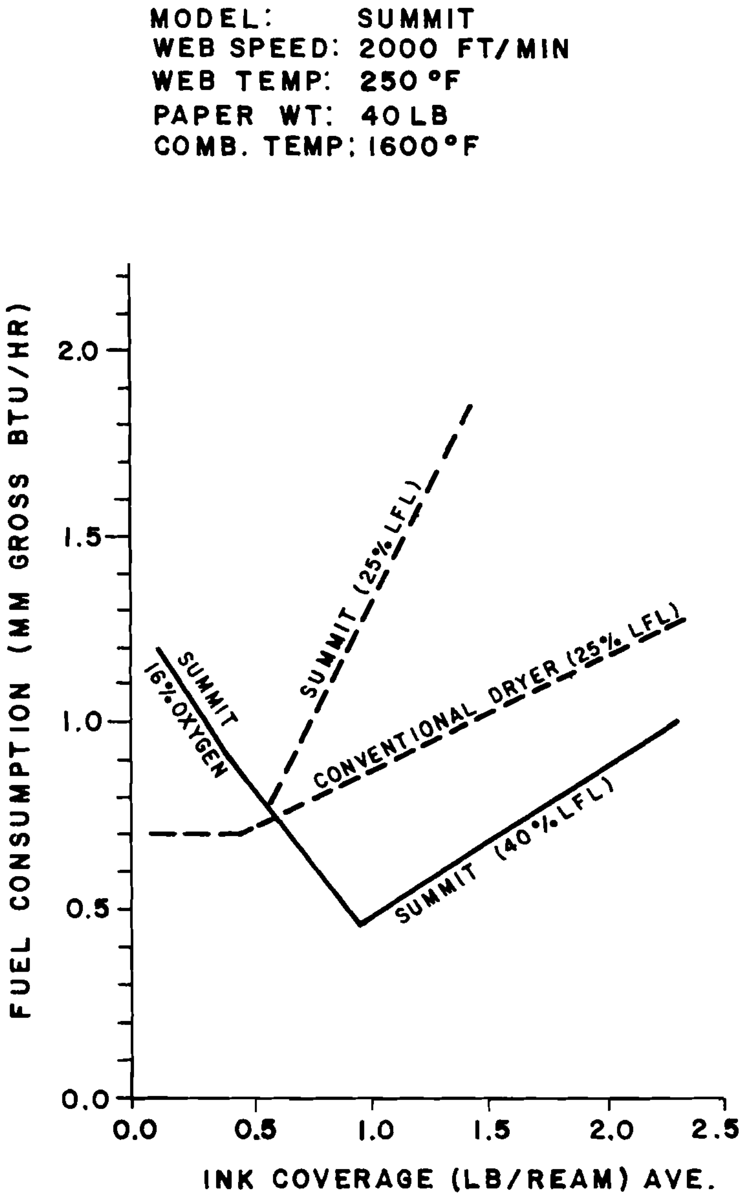
and oxygen concentrations in the stack exhaust and using the accurately measured methane fuel use rate and ink solvent consumption rate. This is possible because the methane fuel and ink solvent both consume oxygen and generate carbon dioxide and known amounts of heat. For example, if a dryer were using 20.5 Nm^3/hr (13 scfm) of natural gas and no solvent and if the carbon dioxide concentration were 4.0% in the exhaust, then the exhaust rate would be:

$$ER = \frac{20.5\ Nm^3}{hr} * \frac{100\%}{4.0\%} = \frac{512\ Nm^3}{hr} \tag{1}$$

ER: exhaust rate
4.0%: carbon dioxide concentration in exhaust stream

It is also possible to quantitate the actual amount of hot return air that comes back to the dryer from the combustion chamber. Again, the carbon dioxide and/or oxygen concenrations in the combustion chamber can be used to estimate the amount of actual hot return air. For example, qualitatively, if the dryer has no carbon dioxide in it, then there is no hot return of combustion products. On the other hand, if the dryer has high levels of carbon dioxide in it, then there is a significant amount of hot return.

The important point here is that the computer projections, such as the ones shown in Figure 3, are reliable.



NOTE: This graph does not include fuel used by the pollution control. The SUMMIT does not need pollution control and is turned off during non-printing times.

Figure 3. Ink Coverage (LBS/Ream) Average

Third Objective - Exhaust Clean-up

Hydrocarbon destruction efficiency as a function of combustion chamber temperature is shown in Table 2 and 3. At 871°C (1600°F) carbon monoxide was below the detection limit of 25 ppm.

Fourth Objective - Fuel Consumption

Table 1A, time 09:53, is typical of fuel consumption with the original burner. In most cases, Wagners has been operating at 1.87 millimeter of mercury (mm Hg) (1.0 inch water column) combustion chamber pressure. In this example, their fuel consumption was 918,000 kiloJoules per hour (kJ/hr) 870,000 [British thermal units per hour (Btu/hr)] at 1.87 mm Hg (1.0 inch water column) compared to a conventional dryer which would be about 861,935 kJ/hr (817,000 Btu/hr) plus whatever additional fuel would be required for pollution control. In this case, conventional pollution control would add about 100,000 to 316,500 kJ/hr (94,786 to 300,000 Btu/hr) to the fuel consumption depending on whether the unit was a catalytic or a thermal afterburner. Because of the low ink coverage, the LFL was also very low so the SUMMIT was operating in a very low efficiency area with respect to fuel consumption. Nevertheless, the fuel consumption was still lower than a conventional system.

With the new burner system, the fuel consumption is about 30% higher.

Fuel consumption in gross kJ/hr can be estimated as follows:

$$FC = [(ER * (Tc-Ta) * 1.47) + WL + RL - (SOL * Hcomb)]/0.9 \quad (2)$$

FC:	Fuel consumption (kJ/hr)
ER:	Exhaust rate at stack (Nm^3/hr)
Tc:	Temperature of combustion (°C)
Ta:	Temperature of ambient air (°C)
1.47:	Conversion factor
WL:	Web heat load (kJ/hr)
RL:	Radiation heat losses (kJ/hr)
SOL:	Ink solvent combusted (kJ/hr)
Hcomb:	Net heat of combustion of ink oil solvent (kJ/kg) (44,191 kJ/kg for Magie oils)
0.9:	Conversion factor from net kJ/hr to gross kJ/hr

Fuel consumption in gross Btu/hr can be estimated as follows:

$$FC = [(ER * (Tc - Ta) * 1.22) + WL + RL - (SOL * H\ comb)]/0.9 \quad (3)$$

FC:	Fuel consumption (Btu/hr)
ER:	Exhaust rate at stack (scfm)
Tc:	Temperature of combustion (°F)
Ta:	Temperature of ambient air (°F)
1.22:	Conversion factor
WL:	Web heat load (Btu/hr)
RL:	Radiation heat losses (Btu/hr)
SOL:	Ink solvent combusted (Btu/hr)
Hcomb:	Net heat of combustion of ink oil solvent (Btu/lb) (19,000 Btu/lb for Magie oils)
0.9:	Conversion factor from net Btu/hr to gross Btu/hr

Fifth Objective - Preprogrammed Start-up

For rapid start-up, it was desirable to bring back as much of the hot combustion products as possible thru the hot return damper to the dryer itself. This required maximum burner firing rate, with maximum combustion air. Thus, high exhaust rates were required during start-up to prevent exfiltration at the web slots. During start-up, the exhaust fan went to maximum operating speed and the exhaust damper went to a pre-selected position near full open.

After the desired web temperature was reached, the fan speed was slowly reduced automatically and the exhaust damper began to close toward a preset minimum as the dryer switched over to LFL control. In this case, the combustion chamber temperature was also reduced because extremely high cleanup rates were not required.

Zoned Drying/Heat Recovery/Catalyst

Although a single zone system field test has been described, Figure 4 shows a multi-zone configuration. In multi-zone systems, the first zone seen by the web would be of the SUMMIT design while zone two would use a conventional dryer. Such an arrangement allows reduction of exhaust stacks while providing for a compact and straight forward arrangement.

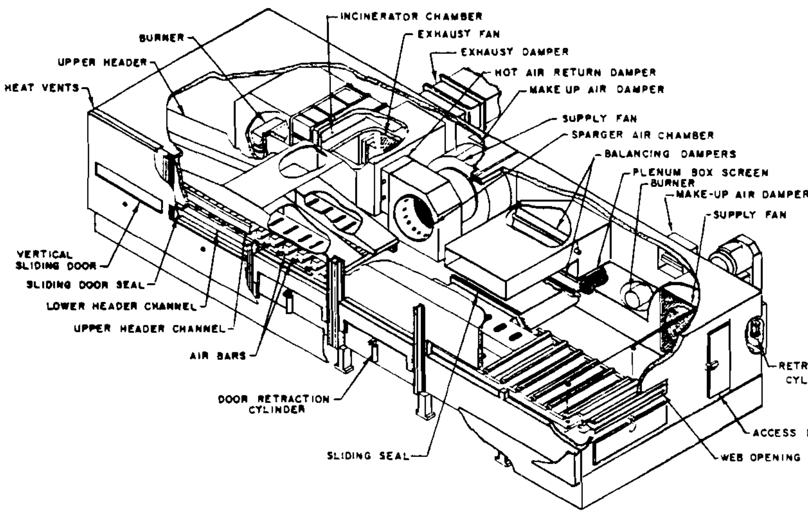


Figure 4. Two Zone Summit Dryer

Heat recovery of the low volume, high temperature exhaust gas can be achieved through the use of refrigeration systems (absorption chillers) providing cold water for press side chill rolls and other operations or through building heating and ventilating systems. Heat recovery is less of an issue with this design since the entire system is turned off during non printing times. With conventional systems, fuel continues to be used during non printing times leading to a very unfavorable fuel usage when compared to the SUMMIT type design.

Installation costs are also greatly reduced since installation of a remote afterburner is no longer required. Expensive ductwork and support structure is also avoided.

Catalysts in the form of monoliths can be used in the dryer combustion chamber. This approach is not usually recommended because of the catalysts need for regular maintenance and the small benefit gained from its use on this type of dryer arrangement.

. Other Benefits

In a typical dryer, moisture covers ranges from .02 lb H_2O/lb dry air to .08 lb/lr. With products of combustion coming directly back to the process, moisture levels will be much higher. Levels as high as .20 lb/lb to .30 lb/lb might be achieved. These elevated moisture levels should aid printers in avoiding quality problems usually associated with heatset web offset printing.

Acknowledgements

We greatly appreciate the help, cooperation, patience, and constructive input from the personnel of Wagners Printers throughout the entire project.

Appendix A

Abbreviations

General	
LFL	lower flammability limit
hr	hour
min	minute
%	percent
Hz	Hertz
<	less than
IPH	impressions per hour
ppmv	parts per million by volume
Metric	
°C	degrees Celsius
cm	centimeter
gm	gram
J	Joule
kg	kilogram
kJ	KiloJoule
m	meter
m^2	square meter
m^3	cubic meter
mm Hg	millimeters of mercury
Nm^3/min	normal cubic meters per minute (0° Celsius)
ream	306.58 square meters
British	
Btu	British thermal unit
Btu/hr	British thermal unit per hour
°F	degrees Fahrenheit
ft	feet
ft^2	square feet
ft^3	cubic feet
in	inch
in W.C.	inches of water column
lb	pound
scfm	standard cubic feet per minute (70 degrees Fahrenheit)
sft^3/min	standard cubic feet per minute (70 degrees Fahrenheit)
ream	3300 square feet