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COATINGS

ECONOMIC AND ENERGY SAVINGS THROUGH COATINGS SELECTION

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ABSTRACT

Shortages of various energy sources are creating great interest in low energy paint systems currently available and under development. Although emphasis is presently on energy conservation and not air or water pollution, it is wise to consider a switch to coatings that not only conserve energy, but also comply with the pollution regulations. In addition to the energy savings attributed to the cure of the coating, a secondary savings can be seen in the reduction of solvent consumption not only in the manufacture of the coating, but also in the quantity of solvent used for paint viscosity adjustment.

ECONOMIC AND ENERGY SAVINGS THROUGH COATINGS SELECTION

At present, the shortages of various energy sources are creating great interest in the low energy paint systems currently available and proposed. A relaxation in the environmental areas is presently being seen as a direct result of the principal concern for energy conservation. Although the emphasis is directed away from water and air pollution at this moment, we are bound to see it return in the very near future, possibly in even greater strength. It is wise to then consider a switch to coatings that not only conserve energy, but also comply with the pollution regulations. Coatings which will meet these criteria will be considered here.

The basic design requirements for the system are centered around a part constructed of twenty four gauge sheet steel which is four feet tall by two feet long by two and one half feet wide. Each part contains forty square feet of metal and weighs forty pounds. Five such units are processed per minute on a three inch monorail conveyor traveling at fifteen feet per minute. The parts are on three foot centers and are supported by indexing hooks weighing ten pounds each. Then twelve thousand square feet of sheet metal weighing twelve thousand pounds are processed every hour. The coatings are applied to give an average dry film thickness (DFT) of one mil.

After coating, the parts receive a seven minute flash prior to baking. The parts then enter a roof mounted bottom entry bake oven. There is 6,300 square feet of oven panel area and the insulated oven panels are five inches thick. The bake time is twenty minutes for the multi-pass direct-fired oven which is 31 feet wide by 67 feet long by 10 feet high. The bake temperature is dependant on the coating. The oven is equipped with two 21,000 cubic feet per minute circulation fans powered by 25 horse power motors.

The coating is applied at one mil dry film thickness to only the outside of the part. In order to provide for safe operation of the oven with a solventborne coating, it is necessary to maintain a 25% Lower Explosive Limit (LEL) for the volatiles expelled in the oven. One gallon of a typical solvent at room temperature will render 2,500 cubic feet of air explosive. To maintain a 25% Lower Explosive Limit, a volume of fresh air equal to four times the explosive volume (10,000 cubic feet of air at 70^{o}F per gallon of solvent) must be brought into the oven. This is accomplished by the exhaust fan.

In the case of the 80/20 waterborne coating, the evaporated liquid contains solvent as well as water in a 20% to 80% ratio respectively. The 25% Lower Explosive Level must be met for the solvent portion of the waterborne coating. In order to maintain a low humidity level within the oven, it may be necessary to introduce 5,000 cubic feet of fresh air at 70^{o}F per gallon of water expelled in the oven. Hence, the exhaust rate for the waterborne coating can be the solventborne portion (25% LEL); the humidity portion or the sum of both.

In the case of a powder coating, volatiles are also expelled in the oven. The recommended ventilation requirement for a powder coating bake oven is 1,440 cubic feet of air at 70^{o}F per pound of volatile.

The paint coatings that will be considered are a conventional 28.6% V.S. thermosetting acrylic, a single component 95% V.S. "Ultra High Solids" polyester (high and low bake), a single component 80% V.S. "High Solids" polyester (high and low bake), a single component 60% V.S. "Medium Solids" polyester (high and low bake), a dual component 80% V.S. "High Solids" urethane, a dual component 50% V.S. "Medium Solids" urethane (high and low bake), a 97% V.S. epoxy powder (high and low bake), a 95% V.S. polyester powder (high and low bake), and 80/20 type 29% V.S. high bake waterborne coating, and 80/20 type 25% V.S. "Catalyzed" waterborne coating and an electrodeposition type waterborne coating (high and low bake). The volume solids of the paints as listed are at the application levels of the coatings. The quantities of each coating consumed per hour can be found in Table I. Please note that the quantities listed are only the amounts of coating necessary to provide a uniform one mil coating on the outside of the part and do not reflect the material losses associated with the application efficiencies of the process or equipment.

The heat loss for the oven is equal to the sum of the heat inputs for the ware, including the conveyor chain, trollies and hangers, the panel loss, the exhaust loss and in the case of the waterborne coatings, the water evaporation loss.

The heat lost by the ware and conveyor can be determined from the relationship: $Q_m = M_m . C_m . \Delta T_m$ where M_m is the weight of the metal (ware, conveyor chain, trollies, and hangers) processed per hour, C_m is the specific heat of the metals and ΔT_m is the difference in the exit metal temperature and the 70°F plant ambient temperature. The heat lost through the oven panels can be determined from the relationship: $Q_p = A_p . P_f . \Delta T_p$ where A_p is the total area of the oven panels, P_f is the panel heat loss factor and ΔT_p is the difference in the oven temperature and the 70°F ambient temperature. The heat loss associated with oven exhaust can then be determined as follows: $Q_a = V_a . \rho_a . C_a . \Delta T_a$ where V_a is the volume of the air referenced to 70°F exhausted per minute, ρ_a is the density of air at 70°F, C_a is the specific heat of air and ΔT_a is the difference in the bake oven temperature and the 70°F ambient temperature. The exhaust requirements for the coatings can be found in Table II. In the case of the high bake waterborne coating, the water evaporation loss is the quantity of heat necessary to raise water from 70°F to 212°F, then from water at 212°F to steam at 212°F to steam at 300°F. The water evaporation loss for the "catalyzed" waterborne coating is the quantity of heat necessary to raise water from 70° to 150°F and to change it to vapor at 150°F. Then the heat loss can be determined from the relationship: $Q_w = M_w . h_w$ where M_w is the weight of the water and h_w is the enthalpy change of the water.

The total heat lost, Q_t is then the sum of the individual losses, i.e. $Q_t = Q_m + Q_p + Q_a$ for the solventborne coatings and $Q_t = Q_m + Q_p + Q_a + Q_w$ for the waterborne coatings. The total heat input for the oven is equal to the total heat lost from the system. Once the total heat input figure in Btu's per hour is calculated, then the expended energy can be determined. The heat requirements for the bake oven are listed in Table III and the natural gas requirements in Table IIIA.

TABLE I

Coating	% V.S.	Paint Consumed (GPH)	Solvent Evaporated (GPH)	Water Evaporated (GPH)	Bake Temperature (°F)
1. Acrylic	28.6	26.14	18.66	-	350
2. "Ultra High Solids" Polyester	95	7.87	0.39	-	Hi 370 Lo 250
3. "High Solids" Polyester	80	9.35	1.87	-	Hi 370 Lo 250
4. "Medium Solids" Polyester	60	12.46	4.98	-	Hi 370 Lo 250
5. "High Solids" Urethane	80	9.35	1.87		180
6. "Medium Solids" Urethane	50	14.95	7.48	-	Hi 260 Lo 150
7. Epoxy Powder	97	7.70	0.22*	-	Hi 340 Lo 275
8. Polyester Powder	95	7.87	0.39**	-	Hi 360 Lo 320
9. 80/20 Waterborne	29	25.78	3.66	14.64	300
10. 80/20 "Catalyzed" Waterborne	25	29.90	4.48	17.94	150
11. Electrodeposition Waterborne	95	7.87	0.16	0.23	Hi 350 Lo 275

* The weight of the epoxy powder is 13.07 pounds per gallon. Then 2.88 pounds of volatiles (0.22 gallons) as plasticizers are expelled per hour.

** The weight of the polyester powder is 12.49 pounds per gallon. Then 4.87 pounds of volatiles (0.39 gallons) as plasticizers are expelled per hour.

TABLE II

OVEN EXHAUST REQUIREMENTS*

CFM at 70°F (SCFM)

Coating	% V.S.	Bake Temp. (°F)	Volatile Portion (SCFM)	Humidity Portion (SCFM)	Burner Portion (SCFM)	Total (SCFM)
1. Acrylic	28.6	350	3,200	NA	NA	3,200
2. "Ultra High Solids" Polyester	95	Hi 350	65	NA	255	320
		Lo 250	65	NA	145	210
3. "High Solids" Polyester	80	Hi 370	320	NA	265	585
		Lo 250	320	NA	180	500
4. "Medium Solids" Polyester	60	Hi 370	830	NA	310	1,140
		Lo 250	830	NA	NA	830
5. "High Solids" Urethane	80	180	320	NA	NA	320
6. "Medium Solids" Urethane	50	Hi 260	1,246	NA	NA	1,246
		Lo 150	1,246	NA	NA	1,246
7. Epoxy Powder	97	Hi 320	73	NA	247	320
		Lo 275	73	NA	177	250
8. Polyester Powder	95	Hi 360	120	NA	240	360
		Lo 320	120	NA	210	330
9. 80/20 Waterborne	29	300	610	1,220	NA	Hi 1,830
			610	NA	240	Lo 850
10. 80/20 "Catalyzed" Waterborne	25	150	747	1,495	NA	Hi 2,242
			747	NA	NA	Lo 747
11. Electrodeposition Waterborne	95	Hi 350	27	19	264	310
		Lo 275	27	19	170	216

* Based on NFPA 86A Article 410.

<u>TABLE III</u>

Coating Type	% Vol. Solids	Bake Temp.	Exhaust Rate	OVEN HEAT LOSSES				
				Ware & Conveyor	Panel	Exhaust Air	Water Evaporation	Total
		°F	SCFM	Btu's/Hour	Btu's/Hour	Btu's/Hour	Btu's/Hour	Btu's/Hour
1. Acrylic	28.6	350	3,200	661,920	529,200	967,680	N. A.	2,158,800
2. "Ultra High Solids" Polyester	95	370 250	320 210	709,200 425,200	567,000 340,200	103,680 40,825	N. A. N. A.	1,379,880 806,225
3. "High Solids" Polyester	80	370 250	585 500	709,200 425,200	567,000 340,200	189,540 97,200	N. A. N. A.	1,465,740 862,920
4. "Medium Solids" Polyester	60	370 250	1,140 830	709,200 425,200	567,000 340,200	369,360 161,352	N. A. N. A.	1,645,560 927,072
5. "High Solids"	80	180	320	206,040	207,900	38,016	N. A.	505,956
6. "Medium Solids" Urethane	50	260 150	1,246 1,246	449,160 189,120	359,100 151,200	255,680 107,655	N. A. N. A.	1,063,940 447,975
7. Epoxy Powder	97	340 275	320 250	638,200 484,620	510,300 387,450	93,312 55,350	N. A. N. A.	1,241,821 927,420
8. Polyester Powder	95	360 320	360 330	685,560 591,000	548,100 472,500	112,752 89,100	N. A. N. A.	1,346,600 1,152,600
9. 80/20 Waterborne	29	300	1,830 850	543,720 543,720	434,700 434,700	454,572 211,140	145,463 145,463	1,578,45[illegible] 1,335,02[illegible]
10. 80/20 "Catalyzed" Waterborne	25	150	2,242 747	189,120 189,120	151,200 151,200	193,708 64,541	156,912 156,912	690,940 561,77[illegible]
11. Electrodeposition Waterborne	95	350 275	310 216	661,920 484,620	529,200 387,450	93,744 47,822	2,331 2,262	1,287,19[illegible] 922,154

TABLE III A

Coating Type	% Vol. Solids	Bake Temp. °F.	Exhaust Rate SCFM	Total Oven Heat Loss Btu's/Hour	NATURAL GAS Quantity CFH	NATURAL GAS Cost $/Hour*
1. Acrylic	28.6	350	3,200	2,158,800	2,159	3.24
2. "Ultra High Solids" Polyester	95	370 250	320 210	1,379,880 806,225	1,380 806	2.07 1.21
3. "High Solids" Polyester	80	370 250	585 500	1,465,740 862,920	1,466 863	2.20 1.29
4. "Medium Solids" Polyester	60	370 250	1,140 830	1,645,560 927,072	1,646 927	2.47 1.39
5. "High Solids" Urethane	80	180	320	505,956	506	0.76
6. "Medium Solids" Urethane	50	260 150	1,246 1,246	1,063,940 447,975	1,064 448	1.60 0.67
7. Epoxy Powder	97	340 275	320 250	1,241,821 927,420	1,242 927	1.86 1.39
8. Polyester Powder	95	360 320	360 330	1,346,412 1,152,600	1,346 1,153	2.02 1.73
9. 80/20 Waterborne	29	300	1,830 850	1,578,455 1,335,023	1,578 1,335	2.37 2.00
10. 80/20 "Catalyzed" Waterborne	25	150	2,242 747	690,940 561,773	691 562	1.04 0.84
11. Electrodeposition Waterborne	95	350 275	310 216	1,287,195 922,154	1,287 922	1.93 1.38

*Based on natural gas at $1.50 per 1,000 cubic feet.

Electrical energy is also expended by the baking process in addition to the natural gas consumed in the bake oven. The electrical requirements for the circulating and exhaust fans can be seen in Table IV.

TABLE IV

Coating	Quantity Kilowatt-hours	Cost* $/hour
1. Acrylic	38.05	1.52
2. "Ultra High Solids" Polyester (95%)	37.43	1.50
3. "High Solids" Polyester (80%)	37.44	1.50
4. "Medium Solids" Polyester (60%)	37.72	1.50
5. "High Solids" Urethane	37.37	1.49
6. "Medium Solids" Urethane	37.62	1.50
7. Epoxy Powder	37.39	1.50
8. Polyester Powder	37.43	1.50
9. 80/20 Waterborne	38.13	1.53
10. 80/20 "Catalyzed" Waterborne	37.87	1.51
11. Electrodeposition Waterborne	37.37	1.49

*Based on electricity at $0.04 per kilowatt-hour

The total cost of operation of the bake oven for each representative coating can be seen on Table V.

TABLE V

		Cost $/hour
1. Acrylic		4.76
2. "Ultra High Solids" Polyester	(Hi Bake)	3.57
	(Lo Bake)	2.71
3. "High Solids" Polyester	(Hi Bake)	3.70
	(Lo Bake)	2.79
4. "Medium Solids" Polyester	(Hi Bake)	3.97
	(Lo Bake)	2.89
5. "High Solids" Urethane		2.25
6. "Medium Solids" Urethane	(Hi Bake)	3.10
	(Lo Bake)	2.17
7. Epoxy Powder	(Hi Bake)	3.36
	(Lo Bake)	2.89
8. Polyester Powder	(Hi Bake)	3.52
	(Lo Bake)	3.23
9. 80/20 Waterborne	(Hi Exhaust)	3.90
	(Lo Exhaust)	3.53
10. 80/20 "Catalyzed" Waterborne	(Hi Exhaust)	2.55
	(Lo Exhaust)	2.35
11. Electrodeposition Waterborne	(Hi Bake)	3.42
	(LO Bake)	2.87

In order to place the proper perspective on the quantity of natural gas which can be saved in the bake oven, we shall consider the conventional thermosetting acrylic as the standard and compare it to the lower energy coatings. This comparison can be seen in Table VI.

TABLE VI

Coating Type	% Vol. Solids	Bake Temp. °F	Natural Gas Required (CFH)	Natural Gas Saved (CFH)
1. Acrylic	28.6	350	2,159	0
2. "Ultra High Solids" Polyester	95	370 250	1,380 806	779 1,353
3. "High Solids" Polyester	80	370 250	1,466 863	693 1,296
4. "Medium Solids" Polyester	60	370 250	1,646 927	513 1,232
5. "High Solids" Urethane	80	180	506	1,653
6. "Medium Solids" Urethane	50	260 150	1,064 448	1,095 1,711
7. Epoxy Powder	97	340 275	1,242 927	917 1,232
8. Polyester Powder	95	360 320	1,346 1,153	813 1,006
9. 80/20 Waterborne	29	300	1,578 1,335	581 824
10. 80/20 Catalyzed" Waterborne	25	150	691 562	1,468 1,597
11. Electrodeposition Waterborne	95	350 275	1,287 922	872 1,237

Further energy savings can result by proper utilization of heat recovery technology (heat pipes, heat exchangers, etc). In other words, up to 75% of the heat which might otherwise be lost to the atmosphere via the oven exhaust can be reclaimed and used elsewhere in the finishing process or in the plant to supplement heating systems. Another method for saving energy involves the use of an LEL monitor and controller to regulate the exhaust rate of the oven. The oven exhaust is reduced and regulated to maintain an LEL of about 40%. This device would permit energy savings not only for the conventional coatings, but also the new low energy coatings, as well.

The quantities of solvents expelled from the bake oven can be seen in Table I. For example, during an hour of operation with the thermosetting acrylic paint (supplied at 40% volume solids and reduced to 28.6% volume solids) 18.66 gallons of solvent are expelled, but with the "High Solids" polyester (80% volume solids), only 1.87 gallons of solvent are expelled. Hence, 16.79 gallons of solvent are conserved per hour of operation. Please note that at present, the "High Solids" polyester can be applied at room temperature with the new high speed rotational application equipment. The cost of 7.45 gallons of a reducing solvent blend is $7.45 per hour for the thermosetting acrylic paint, but the "High Solids" polyester can be applied at no additional cost for reducing solvents with the appropriate application equipment. As the costs of organic solvents go up and the need for non-photochemically reactive solvents increases, the costs of the "low volume solids" paints will also substantially increase.

Until such time that the anti-pollution regulations become a primary concern again the need for non-photochemically reactive solvents will not be so great. The coatings listed in Table I can be made to comply with Southern California's Rule 442 in several ways. First, an afterburner can be used, but additional energy will be consumed unnecessarily. The urethane coatings can be cured without heat and will comply with the California regulation providing that non-photochemically reactive solvents are used. The waterborne coatings can be used in unlimited amounts providing that the volatile content consists of only water and organic solvents and the organic solvents do not comprise more than 20% by volume of the volatiles and the volatile content is not photochemically reactive and the organic solvent does not contact a flame. The "High Solids" coatings can be used in unlimited amounts providing that the volatile content of such material is not photochemically reactive and does not exceed 20% by volume of that material, and more than 50% by volume of the volatile is evaporated before entering a chamber heated above the ambient application temperature and the organic solvent or any material containing organic solvent does not come in contact with an open flame. The "Ultra High Solids" coatings (95% volume solids) can be used in unlimited amounts providing that the volatile content of such coatings is not photochemically reactive and does not exceed 5% by volume of the coating and the organic solvent does not come into contact with an open flame.

One condition of Rule 442 which must be met is that the organic solvent must not come into contact with a flame. The oven considered here is a direct fired oven (open flame) and the organic solvents pass by the burner flame. An indirect fired oven can also be employed, but it can be up to 20% less efficient than the direct fired oven. Another approach is to use electricity to heat the oven, but the costs can be prohibitive (the electricity to heat the oven for the acrylic paint will cost approximately $25.28 per hour, but for the "High Solids" Urethane, the cost will be only $5.92 per hour of operation). Another approach is to use steam for oven temperatures up to 250°F. If a boiler is installed, then it can be fired with almost any acceptable fuel and used to heat pretreatment apparatus as well as the paint bake oven.

We have considered the energy consumed by the bake oven in curing the coating. As we attempt to save energy consumed by the finishing process, we must not forget that each part of the process is essential to an acceptable finished product. In addition, we must consider the anti-pollution laws, and select a coating and process which will also comply with these regulations. Only through close cooperation with the paint supplier, pretreatment supplier and equipment supplier can you insure a finishing system which will not only save energy and meet your finish requirement, but also meet the anti-pollution regulations you face.

(APPENDIX I)

Energy derived from various fuels:

Fuel Type	Average Btu's
Manufactured Gas	500 per cubic foot
Natural Gas	1,000 " " "
Propane Gas	2,500 " " "
Butane Gas	3,300 " " "
Oil - #2 or #3	130,000 " gallon
Electricity	3,415 " kilowatt-hour
Coal	13,000 " pound

(APPENDIX II)

Oven Panel Radiation Loss

Panel Thickness (inches)	Panel Factor P_f (Btu's/Square Foot °F Hour)
2"	0.50
4"	0.35
5"	0.30
6"	0.25
8"	0.20

(APPENDIX III)

Typical Oven Calculations

A. Panel Loss

$$Q_P = A_P \cdot P_f \cdot \Delta T_P$$

$$Q_P = (6{,}300 \text{ square feet}) \left(\frac{0.3 \text{ Btu's}}{\text{sq. ft. } ^\circ\text{F hr.}}\right) (180^\circ\text{F} - 70^\circ\text{F})$$

$$Q_P = 207{,}900 \ \frac{\text{Btu's}}{\text{hour}}$$

B. Ware & Conveyor Load

For a three inch monorail conveyor operating at fifteen feet per minute.

Conveyor Chain	-	2,000 pounds per hour
Trollies	-	2,700 pounds per hour
Hooks	-	3,000 pounds per hour
Ware		12,000 pounds per hour

$$Q_m = M_m \cdot C_m \cdot \Delta T_m$$

$$Q_m = \left(19{,}700 \ \frac{\text{pounds}}{\text{hour}}\right) \left(\frac{0.12 \text{ Btu's}}{\text{pound } ^\circ\text{F}}\right) (180^\circ\text{F} - 70^\circ\text{F})$$

$$Q_m = 260{,}040 \text{ Btu's/hour}$$

C. Exhaust Load

$$Q_a = V_a \cdot \rho_a \cdot C_a \cdot \Delta T_a$$

$$Q_a = \left(320 \ \frac{\text{cubic feet}}{\text{minute}}\right)\left(60 \ \frac{\text{min.}}{\text{hour}}\right)\left(\frac{0.075 \text{ pounds}}{\text{cubic foot}}\right)\left(\frac{0.24 \text{ Btu's}}{\text{pound } ^\circ\text{F}}\right)(180^\circ\text{F} - 70^\circ\text{F})$$

$$= 38{,}016 \ \frac{\text{Btu's}}{\text{hour}}$$

D. Water Evaporation Load

Water from 70°F to 212°F= 142 $\frac{\text{Btu's}}{\text{pound}}$

Water from 212°F to steam 212°F = 970 $\frac{\text{Btu's}}{\text{pound}}$

Steam from 212°F to steam at 300°F = 80.8 $\frac{\text{Btu's}}{\text{pound}}$

APPENDIX III
Cont'd......

$$Q_w = \dot{M}_w \cdot h_w$$

$$Q_w = \left(122 \frac{\text{pounds}}{\text{hour}}\right)\left(1192.8 \frac{\text{Btu's}}{\text{pound}}\right)$$

$$Q_w = 145{,}521.6 \text{ Btu's per hour}$$

NOTE: The enthalpy change for the 300°F waterborne coating is 1192.8 Btu's per pound and for the 150°F waterborne coating is 1050.0 Btu's per pound. The enthalpy change for 350°F is 1216.4 Btu's per pound and for 275°F is 1180.9 Btu's per pound.

(APPENDIX IV)

Exhaust Requirements

I. Solventborne Coatings:

$$V_a = \left(\frac{\text{3 gallons of solvent}}{\text{hour}}\right)\left(\frac{\text{1 hour}}{\text{60 min}}\right)\left(\frac{\text{10,000 cubic feet of air @ 70°}}{\text{gallon}}\right)$$

$$V_a = 500 \text{ cubic feet of air at } 70° \text{ per minute}$$

or

$$V_a'' = \frac{\text{Oven Burner Rating}}{(95)\ (60)}$$

For

$V_a'' > 1/3$ Va, assume V_a'' +Va; For $V_a'' < 1/3$ Va* assume Va.

II. Waterborne Coating:

A. Solvent Portion:

Assume 15 gallons of liquid expelled per hour

$$V_a = \left(15 \frac{\text{gallons}}{\text{hour}}\right)(0.20)\left(10{,}000 \frac{\text{cubic feet of air @ 70°F}}{\text{gallon}}\right)\left(\frac{\text{1 hour}}{\text{60 min}}\right)$$

$$V_a = 500 \text{ cubic feet of air at 70°F per minute}$$

B. Water Portion:

$$V_a' = \left(15 \frac{\text{gallons}}{\text{hour}}\right)(0.80)\left(5{,}000 \frac{\text{cubic feet per min. @ 70°F}}{\text{gallon}}\right)\left(\frac{\text{1 hour}}{\text{60 min}}\right)$$

$$V_a' = 1{,}000 \text{ cubic feet of air @ } 70° \text{ per minute}$$

The Total = $V_a + V_a'$ = 1,500 cubic feet @ 70°F per minute

* Refer to NFPA 86A Article 410.

APPENDIX IV
Cont'd.....

III. Powder Coating:

Assume a 3% volume loss.

$$V_a = \left(5 \frac{\text{gallons}}{\text{hour}}\right)(0.03)\left(1{,}440 \frac{\text{cubic feet}}{\text{pound}}\right)\left(13.07 \frac{\text{pounds}}{\text{gallon}}\right)\left(\frac{1 \text{ hour}}{60 \text{ min}}\right)$$

V_a = 47 cubic feet of air at 70°F per minute.

or

$$V''_a = \frac{\text{Oven Burner Rating}}{(95)(60)}$$

For

$V''_a < 1/3\ Va$, assume Va; For $V''_a > 1/3\ Va$ assume $Va + V''_a$

Please note that the exhausts may have to be increased to prevent the oven from fouling.

(APPENDIX V)

Specific Heats of Various Materials

Material	Specific Heat
Air 212°F (1ATM)	0.24
Aluminum	0.20
Brass	0.11
Bronze	0.12
Copper	0.10
Glass	0.19
Magnesium	0.25
Steel	0.12
Water	1.0
Wood (pine)	0.67
Zinc	0.10