DEMONSTRATION OF A NITROGEN BASED CARBURIZING ATMOSPHERE

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ABSTRACT

Energy consumption tests have been completed on a Radiant Tube Box (RTB) furnace which has a fibrous insulation. On this furnace an average of 9.7% of the energy used in processing parts with the conventional endothermic atmosphere practice was saved using nitrogen based atmosphere systems. Furthermore, the natural gas required at the heat treating facility to process the parts was reduced an average of 28.7%.

Energy consumption of the furnace while idling under a methanol atmosphere was determined. When combined with the earlier reported data on endothermic and pure nitrogen atmospheres a linear relationship between energy consumption and hydrogen concentration of the furnace atmosphere was found.

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INTRODUCTION

During this quarterly period, two types of energy consumption tests were performed. Both were on a Radiant Tube Box (R.T.B.) furnace which has a fibrous insulation.

The first was the energy consumed by the furnace while idling with pure methanol as an atmosphere. The data collected during this test is compared with the earlier reported figures for idling energy consumption for nitrogen and endothermic atmospheres.

The second series of tests measured the energy consumed by the furnace during processing of actual parts. Three different atmosphere systems were studied and two different type parts were processed with each atmosphere system.

IDLE TESTS

Procedures:

During the idle tests on the RTB furnace, the amount of natural gas used to fire the furnace was measured while methanol was used as an atmosphere. A positive displacement gas meter (Appendix A) was placed on the inlet gas line to the furnace to measure the amount of natural gas used by the pilots and burners of the furnace. Methanol was sprayed directly into the furnace via a spray nozzle placed in the atmosphere inlet line. One hundred standard cubic feet per hour (SCFH) of methanol vapor was injected in the furnace. This produces an atmosphere of 300 SCFH which is 66.6% hydrogen and 33.3% carbon monoxide via the reaction:

After setting the furnace temperature to 1700°F and allowing the furnace to stabilize for two hours with the methanol atmosphere the test was begun. Times and gas meter readings were simply recorded at the completion of each firing cycle. After correcting the natural gas consumptions to Standard Cubic Feet (SCF), the hourly rates were calculated.

Results

Using 100 SCFH of pure methanol which produces 300 SCFH of atmosphere, the rate of natural gas consumption was 635 SCFH. This is 7.8% higher than the fuel consumption with 300 SCFH flow of endothermic atmosphere, and 26.2% higher than with 300 SCFH of nitrogen atmosphere. These figures are shown in Table I.

The higher idle energy consumption is due to the higher levels of hydrogen in the atmosphere. Since hydrogen has over seven times the thermal conductivity of nitrogen, the heat losses of a furnace are directly related to the hydrogen concentration of the atmosphere.

The effect of hydrogen in the atmosphere is reported by Hotchkiss and Webber¹. They found the energy consumption of an electrically heated box furnace increased linearly with hydrogen concentration of the atmosphere. The Hotchkiss and

¹ Hotchkiss and Webber, "Protective Atmospheres," John Wiley and Sons, Inc., New York, 1953. pp 31-35.

Webber information is shown in Figure 1 and the Air Products data is shown in Figure 2. In both cases energy consumption required to keep the furnace at temperature is plotted against hydrogen concentration of the atmosphere. Although both figures show a linear relationship between hydrogen concentration and energy consumption, a direct comparison of the data requires further analyses.

Figure 3 gives a comparison of the data by plotting the percentage change in fuel consumption against H_2 concentration of the atmosphere. From this figure, it is evident that the effect of hydrogen was more pronounced in the Hotchkiss and Webber furnace. This is due mainly to differences in insulating material (the RTB furnace has fibrous insulation whereas the Hotchkiss and Webber furnace is assumed to have had conventional brick insulation). Heating method (electric vs. gas), and internal design of the furnace (electric elements vs. gas radiant tubes) may also be factors.

Conclusion

The above information is extremely useful in that it proves conclusively the advantages of using a nitrogen atmosphere during idle furnace periods. The energy savings over endothermic atmosphere in idling the RTB furnace at 1700°F was found to be 14.6%. The Hotchkiss and Webber data indicates this savings for other type furnaces could be in the area of 19.5%.

The above information can not be directly correlated to production conditions either with pure nitrogen atmospheres for neutral hardening or nitrogen-based carburizing atmospheres. To analyze production energy consumption the following series of tests were performed.

PRODUCTION TESTS (RTB)

These tests were performed to evaluate the total energy consumed in heat treating parts while employing different atmospheres. Each test consisted of heat treating a load of parts in a specific atmosphere system. During the test, the atmosphere flows and the natural gas consumed in firing the furnace were measured. An energy study was performed to compare the atmosphere systems.

Procedures

Each load of a specific part was made up of approximately the same number of pieces, weighed and recorded. Shims and sample pieces were placed in the load in similar locations. Each load was then processed using the same parameters. A volumetric gas meter (Appendix A) was placed on the natural gas line and recorded the amount of natural gas to the burners and pilots.

Gas meter and atmosphere flow readings were taken:

1. When the furnace was loaded.
2. As the burners stopped firing at heatup.

3. At one-hour intervals.
4. Just prior to force cool.
5. At low temperature.
6. When the furnace was unloaded.

Two different parts with different cycle requirements were processed.

1. 1700°F carbonitride 2-1/2 hours at heat. Force cool to 900°F and remove. Approximately 1750 lb loads. Carbon level .9%. Material 1010.
2. 1750° carbonitride. Hold 1/2 hour at 1400° during heatup for heating uniformity. Six hours at 1750°F. Force cool to 900°F and remove. Approximately 1350 pound loads. Carbon level .9%. Material 1018.

The three different atmospheres used were:

1. Endothermic atmosphere enriched with natural gas. Carbon level controlled by infrared CO₂ analyzer.
2. Nitrogen-natural gas-CO₂ blended and injected in the furnace. Carbon level controlled by blend ratios.
3. Nitrogen-methanol enriched with natural gas. Carbon level controlled by (CO)²/CO₂ ratio from chromatograph and infrared units.

Results

Due to the inability to quench the parts in this type furnace a quantitative comparison of case depths and carbon levels could not be made. However, all parts processed received the standardized cycle times, passed the quality control requirements, and were shipped to the customer.

A study of the energy used to process the load in the furnace was performed to compare the atmosphere systems. This energy comparison is shown in Table II.

The BTU conversions used:

Natural Gas (average energy content)	1,000 BTU's/SCF
Endothermic Atmosphere (average energy required to produce)	350 BTU's/SCF
Nitrogen (average energy required to produce)	350 BTU's/SCF
CO ₂ (average energy required to produce)	106 BTU's/SCF
Methanol (average energy required to produce)	130,000 BTU's/gal

Table II indicates energy savings of from 8.3% to 11.5% using either nitrogen system. Also shown in Table II is a comparison of the natural gas consumed at the heat treating facility in processing the parts with the different atmospheres. Natural gas savings ranged from 26.5% to 30.7% with the nitrogen atmosphere systems. Although the natural gas savings do not reflect lower total energy consumption, these savings could be important to the heat treater during periods of natural gas curtailment.

Conclusion

In this furnace both the nitrogen atmosphere systems resulted in an overall energy savings while processing parts when compared to the traditional endothermic atmosphere. The average overall energy savings was 9.7%. This savings combined with the idle energy savings of from 14.6 to 19.5% is a significant energy savings for the heat treating industry.

Furthermore, based on this furnace, the amount of natural gas consumed at the heat treating facility could be reduced an average of 28.7% using a nitrogen atmosphere system. This could be very significant during periods of natural gas curtailment.

NEXT PERIOD

Similar tests as reported above will be performed on an integral quench batch furnace and a continuous belt furnace. The continuous furnace information should further define energy and gas savings and also allow for a very accurate determination of part quality for the different atmosphere systems.

APPENDIX A
EQUIPMENT INFORMATION

GAS METERS

Serial Number:	W72810T, W72926T and W72957T	S6047670
Type:	Rockwell #750 3-78	Rockwell E-78
Capacity:	1600 CFH @ 2" differential 750 CFH @ 1/2" differential	5000 CFH @ 2" differential 2500 CFH @ 1/2" differential
Pressure Max:	20 psi	100 psi
Temp. Compensation Range:	-30°F to 120°F	-30°F to 120°F
Maximum Operation Temp:	+165°F	+165°F
Temp. Compensated to:	60°F	60°F

FURNACES

Power Convection - Super Allcase

BX 37304-1

1,000,000 BTU/hr

Power Convection - Radiant Tube Box (RTB)

BX 37306-1

1,000,000 BTU/hr

TABLE I
IDLE HEATING REQUIREMENTS

RTB

<u>Atmosphere</u>	<u>Flow Rate SCFH</u>	<u>Natural Gas Consumed by Burners + Pilots (SCFH)</u>	<u>Savings with N₂</u>	
			<u>SCFH</u>	<u>%</u>
<u>Old Lining</u>				
Endothermic	800	613		
Nitrogen	800	542	71	11.5%
Endothermic	300	555		
Nitrogen	300	499	56	10.1%
<u>New Lining</u>				
Endothermic	800	602		
Nitrogen	800	559	43	7.1%
Endothermic	300	589		
Nitrogen	300	503	86	14.6%
Methanol (100%)	100*	635		

*Produces 300 SCFH of atmosphere which is 66.6% H₂ and 33.3% CO.

TABLE II
ENERGY AND NATURAL GAS SAVINGS

<u>Atmosphere</u>	<u>Date</u>	<u>BTU's To Produce Carrier Gas (1,000 BTU)</u>	<u>BTU's Enrich Gas (1,000 BTU)</u>	<u>Total BTU's To Produce Atmosphere (1,000 BTU)</u>	<u>BTU's Burners (1,000 BTU)</u>	<u>Total BTU's To Process Parts (1,000 BTU)</u>	<u>Total Energy Savings With N₂ System %</u>	<u>Total Natural Gas Consumed by Heat Treating Facility to Process Parts</u>	<u>Natural Gas Savings %</u>
<u>2-1/2 HOUR CARBONITRIDE AT 1700°F</u>									
Endothermic	5/10/79	2,017	308	2,325	4,308	6,633		6,633	
N ₂ -CH ₄ -CO ₂	5/15/79	1,206	511	1,717	3,824	5,541		4,335	
N ₂ -CH ₄ -CO ₂	6/26/79	1,202	705	1,907	4,722	6,629		5,427	
Avg. of 2 Runs		1,204	608	1,812	4,273	6,085	8.3	4,881	26.4
N ₂ -Methanol	6/20/79	1,269	205	1,474	4,417	5,891		4,622	
N ₂ -Methanol	6/29/79	1,545	165	1,710	4,406	6,116		4,571	
Avg. of 2 Runs		1,407	185	1,592	4,412	6,004	9.5	4,596	30.7
<u>SIX HOUR CARBONITRIDE AT 1750°F</u>									
Endothermic	6/21/79	2,759	444	3,203	6,397	9,600		9,600	
N ₂ -CH ₄ -CO ₂	5/16/79	1,971	807	2,778	5,903	8,681		6,710	
N ₂ -CH ₄ -CO ₂	7/5/79	1,349	850	2,199	6,107	8,306		6,957	
Avg. of 2 Runs		1,660	828	2,489	6,005	8,493	11.5	6,834	28.8
N ₂ -Methanol	6/19/79	1,795	359	2,154	6,426	8,580		6,785	
N ₂ -Methanol	7/26/79	1,877	183	2,060	6,710	8,770		6,893	
Avg. of 2 Runs		1,836	271	2,107	6,568	8,675	9.6	6,839	28.8

*FURNACE ENERGY CONSUMPTION
IDLE AT 1700°F*

FIGURE 1.

*FURNACE ENERGY CONSUMPTION
IDLE AT 1700°F*

FIGURE 2.

**EFFECT OF HYDROGEN ON ENERGY CONSUMPTION
IDLE AT 1700°F**