CONS-5058-T2

DEMONSTRATION OF A NITROGEN BASED CARBURIZING ATMOSPHERE

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TABLE VI
(continued)

ENERGY BREAKDOWN

1700°F Carbonitride - Two Hours at Heat

Atmosphere	Time Into Cycl. (Hrs)	Time Interval Between Readings (Hrs)	Natural Gas Consumed During Time Interval (SCFH)				Burner Gas Consumption During Time Interval (SCFH)
			Pilots & Enriching	Quench Tank	Flame Screen	Total	
N ₂ -CH ₄ -Air 2	0						
	.1186						
	1.0381	1.0381	82			1250	1125
	1.5422	.5041	40	1	1	344	599
	2.0867	.5445	44			317	501
	2.4831	.3964	35		1	237	507
	3.0269	.5438	2			228	416
	3.2006	.1737	4	1		57	299
	3.7408	.5402	12			150	255
Methanol	0						
	.1250						
	.9861	.9861	22	5	1	1169	1157
	1.5839	.5978	76	3		431	589
	1.985	.4011	36	2	1	222	456
	2.4528	.4678	46	2		285	507
	3.0333	.5805	33	2	1	270	403
	3.6828	.6495	16	5		218	303

TABLE VI
ENERGY BREAKDOWN

1700°F Carbonitride - Two Hours at Heat

Atmosphere	Time Into Cycl. (Hrs)	Time Interval Between Readings (Hrs)	Natural Gas Consumed During Time Interval (SCFH)				Burner Gas Consumption During Time Interval (SCFH)
			Pilots & Enriching	Quench Tank	Flame Screen	Total	
Endothermic	0						
	.1167						
	1.1167	1.1167	17	3	1	1286	1133
	1.7181	.6014	97	1	0	445	577
	2.2128	.4947	55	1	1	323	538
	2.6833	.4705	62	1	0	248	393
	3.15	.4667	60	1	1	204	304
N ₂ -CH ₄ -CO ₂	0						
	.0744						
	.9494	.9494	23		1	1136	1171
	1.5550	.6056	15			407	647
	2.1411	.5861	15			322	524
	2.6161	.4750	11			250	503
	2.9911	.3750	9			157	395
	3.1078	.1167	2			59	488
	3.5494	.4416	10	1	1	146	303
N ₂ -CH ₄ -Air 1	0						
	.0861						
	1.0542	1.0542	24			1214	1129
	1.5494	.4952	11		1	315	612
	2.0653	.5159	38			311	529
	2.5944	.5291	42			309	505
	3.0361	.4417	36			207	387
	3.1722	.1361	10		1	98	639
	3.6967	.5245	42			217	333

TABLE V
ENERGY BREAKDOWN

1700°F Carburize - Three Hours at Heat

Atmosphere	Time Into Cycl. (Hrs)	Time Interval Between Readings (Hrs)	Natural Gas Consumed During Time Interval (SCFH)				Burner Gas Consumption During Time Interval (SCFH)
			Pilots & Enriching	Quench Tank	Flame Screen	Total	
N ₂ -CH ₄ -CO ₂	0						
	.0381						
	1.0631	1.0631	80	4	1	1359	1198
	1.6047	.5416	21	2	0	348	600
	2.0547	.4500	27	1	1	246	482
	2.5662	.5115	30	2	0	246	418
	3.0617	.4955	30	2	0	295	531
	3.6311	.5694	35	2	1	301	462
	4.2725	.6414	39	2	0	209	262
	4.8214	.5489	34	2	2	178	255
Endothermic	0						
	.133						
	1.1917	1.1917	30	3	12	1431	1163
	1.7547	.5630	72	1	0	401	583
	2.2111	.4564	62	1	0	291	500
	2.7892	.5781	66	2	1	348	483
	3.2758	.4866	45	1	1	269	456
	3.7500	.4742	44	2	1	252	432
	4.4078	.6578	55	2	1	242	280
	4.9564	.5486	31	0	1	171	253
Alcohol	0						
	.1181						
	1.1811	1.1811	77	1		1385	1107
	1.7658	.5847	95		1	432	575
	2.2533	.4875	73	1		301	466
	2.7686	.5153	52			299	479
	3.1550	.3864	28		1	204	453
	3.6742	.5192	74	1		308	449
	4.1833	.5091	78			310	456
	5.2714	1.0881	160		1	403	222

TABLE IV
ENERGY BREAKDOWN

1550°F Neutral Hardening - 40 Minutes at Heat

Atmosphere	Time Into Cycl. (Hrs)	Time Interval Between Readings (Hrs)	Natural Gas Consumed During Time Interval (SCFH)				Burner Gas Consumption During Time Interval (SCFH)
			Pilots & Enriching	Quench Tank	Flame Screen	Total	
Endothermic	0						
	.1292						
	.9492	.9492	93	3	9	1188	1140
	1.4292	.4800	13	1	1	273	538
	1.6625	.2333	5	1	1	59	222
N ₂	0						
	.1456						
	1.0889	1.0889	63		1	1242	1082
	1.7372	.6483	38	1	1	372	512
N ₂ -CH ₄ -Air	0						
	.1133						
	1.1711	1.1711	38	6		1347	1113
	1.8733	.7022	17	4	1	320	424
Alcohol	.1569						
	.9903	.9903	61	1		1176	1125
	1.6978	.7075	43		1	355	440

TABLE III
ENERGY BREAKDOWN

1600°F Carbonitride - One Hour at Heat

Atmosphere	Time Into Cycl. (Hrs)	Time Interval Between Readings (Hrs)	Natural Gas Consumed During Time Interval (SCFH)				Burner Gas Consumption During Time Interval (SCFH)
			Pilots & Enriching	Quench Tank	Flame Screen	Total	
Endothermic	0						
	.128						
	.874	.874	33	2		974	1074
	1.394	.521	53	2		302	474
	1.811	.417	49	1	1	209	379
N ₂ -CH ₄ -CO ₂	0						
	.104						
	.879	.879	40	1	15	1068	1151
	1.425	.468	31			372	624
	2.009	.554	43		1	330	490
N ₂ -CH ₄ -Air	0						
	.144						
	.875	.875	72	5	1	1086	1152
	1.343	.468	39	2	0	298	549
	1.897	.554	37	3	0	281	435

TABLE II
ENERGY SUMMARY
SUPER ALLCASE

Atmosphere	Wt.	Time to Ht	Total Time	Total Natural Gas to Burners	Fuel/lb	Fuel/Hr	Fuel lb-Hr
	(lbs)	(Hrs)	(Hrs)	(SCF)	($\frac{\text{SCF}}{\text{lb}}$)	($\frac{\text{SCF}}{\text{Hr}}$)	($\frac{\text{SCF}}{\text{lb-Hr}}$)
1600°F Carbonitride - 1 hour at heat							
Endothermic	1304	.874	1.811	1340	1.028	739.9	.567
N ₂ -CH ₄ -CO ₂	1370	.879	2.009	1639	1.196	815.7	.595
N ₂ -CH ₄ -Air	1295	.875	1.897	1506	1.163	793.9	.613
1550°F Neutral Hardening - 40 minutes at heat							
Endothermic	1706	.949	1.663	1393	.816	838.0	.491
Nitrogen	1785	1.089	1.737	1509	.845	868.6	.487
N ₂ -CH ₄ -Air	1740	1.171	1.873	1603	.921	855.7	.492
Methanol	1455	.990	1.698	1425	.979	839.0	.577
1700°F Carburize - three hours at heat							
Endothermic	1258	1.192	4.956	2973	2.363	599.8	.477
N ₂ -CH ₄ -CO ₂	1241	1.063	4.821	2862	2.306	593.8	.478
Methanol	1400	1.181	5.271	2995	2.139	568.2	.406
1700°F Carbonitride - two hours at heat							
Endothermic	1412	1.117	3.150	2192	1.552	695.9	.493
N ₂ -CH ₄ -CO ₂	1347	.949	3.549	2404	1.785	677.3	.503
N ₂ -CH ₄ -Air	1490	1.054	3.697	2466	1.655	667.0	.448
N ₂ -CH ₄ -Air	1447	1.038	3.741	2340	1.617	625.5	.432
Methanol	1594	.9861	3.683	2346	1.471	637.0	.400

TABLE I
IDLE HEATING REQUIREMENTS

RTB

Atmosphere	Flow Rate SCFH	Natural Gas Consumed by Burners + Pilots (SCFH)	Savings With N ₂ SCFH %	
<u>Old Lining</u>				
Endothermic Nitrogen	800	613	71	11.5%
	800	542		
Endothermic Nitrogen	300	555	56	10.1%
	300	499		
<u>New Lining</u>				
Endothermic Nitrogen	800	602	43	7.1%
	800	559		
Endothermic Nitrogen	300	589	86	14.6%
	300	503

BURNER RATE VS. TIME INTO CYCLE

PIPING SCHEMATIC - SUPER ALLCASE FURNACE

FIGURE 1

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	5000 CFH @ 2" differential
	750 CFH @ 1/2" differential	2500 CFH @ 1/2" differential
Pressure Max:	20 psi	100 psi
Temp. Compensation Good:	-30°F to 120°F	-30°F to 120°F
Max. Operating Temp:	+165°F	+165°F
Temp. Compensated to:	60°F	60°F
Min. Operating Temp:		
Rangability:		

FURNACES

Power Convection - Super Allcase
BX 37304-1
1,000,000 BTU/Hr

Power Convection - Radiant Tube Box (RTB)
BX37306-1
1,000,000 BTU/Hr

NEXT PERIOD

Data will be collected on four furnaces employing three different atmospheres over the next six month period. This data when combined with the extensive part evaluation should give a comprehensive evaluation of the three atmosphere systems being studied.

Samples of various alloys which are typically used for furnace fixtures have been obtained and will be evaluated for deterioration when subjected for an extended period of time to different furnace atmospheres.

Four types of production loads were processed in the furnace with four different atmosphere systems. The four production cycles were:

1. One hour carbonitride at 1600°F (20 minute hold at temperature to promote uniform case depth) carbon level .8% - material 12L14..
2. Forty minute neutral hardening at 1550°F - quench - carbon level .4% - material 5140.
3. Three hour carburize at 1700°F - drop temperature to 1550°F for thirty minutes and quench - carbon level .9% - material 8620.
4. Two hour carbonitride at 1700°F - drop temperature to 1625°F for thirty minutes and quench - carbon level .9% - material 1010.

Each type part was processed using the following atmospheres:

1. Endothermic atmosphere enriched with natural gas (when necessary). Carbon controlled automatically by infra-red carbon dioxide analyzer. Endothermic flow 500 SCFH. Natural gas flow as adjusted by carbon dioxide analyzer.
2. Nitrogen-natural gas-carbon dioxide blended and injected in the furnace. Carbon controlled by flow rate adjustment. Nitrogen flow 500 SCFH. Natural gas and carbon dioxide flow totaled 125 SCFH.
3. Nitrogen-natural gas-air blended and injected in the furnace. Carbon controlled manually by analyses of CO^2/CO_2 ratio of furnace gases as analyzed by infra-red carbon dioxide and gas chromatograph. Total flow maintained between 250-300 SCFH. During quench 400 SCFH of nitrogen added for ten minutes to reduce possibility of quench tank fires.
4. Nitrogen-methanol-natural gas. Nitrogen and natural gas pre-mixed. Methanol spray injected into the atmosphere just prior to the atmosphere entering the furnace. Carbon controlled by infra-red carbon dioxide unit. Nitrogen flow 140 SCFH - methanol flow 1/2 gal/hour or 36.5 SCFH. Natural gas as required by the carbon dioxide level. During quench 400 SCFH of nitrogen added for ten minutes to reduce possibility of quench tank fires.

Each production load was weighed prior to being heat treated. After allowing the furnace to stabilize at the required temperature with atmosphere, the parts were loaded in the standard manner. Gas meter readings were taken:

1. As the inner door opened and the load was charged.
2. When the furnace came to temperature.
3. At thirty minute intervals during the cycle.
4. As the inner door was opened to quench the load.

All readings except the first and last were taken immediately at the completion of a firing cycle. Dew points; infra-red carbon dioxide readings; and gas chromatograph analysis for hydrogen, carbon dioxide, nitrogen, methane, and carbon monoxide were obtained every half hour while the load was at heat.

RESULTS

Part 1:

The idle heating requirements for the RTB furnace using endothermic and nitrogen atmospheres are shown in Table I. It is interesting to note that the heating requirements did not appear to change when the deteriorated lining was replaced. The energy saved when idling with a nitrogen atmosphere in this furnace ranged from 7% to 14% when compared to endothermic atmosphere.

Part 2:

Results on the production load tests which were performed in the Super Allcase are summarized in Table II. Since each load of the same type part was of a slightly different weight and was in the furnace for a slightly different length of time, a direct comparison of natural gas required by the furnace burners during the cycle is not adequate. Therefore, the amount of fuel/lb, fuel/hr, and fuel/lb-hr are also given in this Table. Still, no definite conclusion can be drawn.

Therefore, another approach to the data must be taken. A study of the rate of natural gas consumption of the furnace burners appears to be the best approach.

Tables III, IV, V, and VI give a breakdown of the energy data in this manner. The last column in each table gives the natural gas consumption rate of the burners for the interval of time between readings. In other words, the first rate for each load is the burner consumption rate during heat up. The next rate is the burner consumption rate requirements from heat up until the reading was taken. Each succeeding rate reflects the average rate for the preceding half hour.

Since the burners are firing continually during the heat up period, this heat up rate should be the same for all loads processed. A statistical analyses of this rate for the fifteen loads processed gives an indication of the measurement error and thus the accuracy of the data collected. This analyses showed a mean rate of 1137.7 SCFH with a standard deviation of 32.8 SCFH or 2.9% of the mean.

Figure III plots the burner rates vs. time into the cycle for the loads processed at 1700°F. Assuming the same accuracy as was obtained for the heat up rate, an approximate average value line and the two standard deviation value lines are shown. From this analyses there appears to be no measurable difference in the heating requirements using the four different atmospheres at 1700°F. However, additional testing is required to reach a definite conclusion on the fuel consumption question.

A similar comparison of the systems at 1550°F and 1600°F is not given at this time due to the limited number of data points.

CONCLUSION

With the limited data obtained thus far, no conclusion on the effect of furnace atmosphere on the production heating requirements could be made. Additional production data will be collected as the program progresses.

The idle energy consumption on the furnace with fibrous insulation was from 7 to 14% less with nitrogen than with endothermic atmosphere.

DESCRIPTION OF PROJECT

The main emphasis of this phase of the program is an analyses of what effect furnace atmosphere has on the heating energy requirements of heat treating furnaces. To this date two types of energy consumption tests have been performed:

1. Idle natural gas consumption on a batch furnace which has a fibrous insulation. Tests were originally performed with a badly deteriorated lining and repeated after a new lining was installed.
2. Preliminary tests on the natural gas consumed by an integral quench batch furnace while parts are being processed. Four different parts have been processed using four different atmospheres in this furnace.

The parts processed during these tests are being evaluated to insure similar heat treating results are being obtained with all four atmosphere systems.

PROCEDURE

Part 1. Idle energy consumption:

The first tests under this part of the program were performed to determine the idle heating natural gas requirements for a horizontal radiant tube box (RTB) furnace while different atmospheres were in the furnace. These tests were originally performed while the furnace had badly deteriorated fibrous insulation. After replacing the fibrous insulation, the tests were repeated.

A Rockwell diaphragm gas meter (appendix A) was installed on the natural gas line to determine the amount of fuel consumed by the furnace. Atmosphere was injected into the furnace via an inlet port in the top of the furnace behind the fan.

After setting the furnace temperature to 1700°F, each test consisted of flowing atmosphere into the furnace until the old atmosphere was sufficiently purged out. Gas meter readings were taken periodically, but always at the completion of a firing cycle. Meter readings, pressure, and times were recorded. The hourly flow rates were calculated and corrected for temperature and pressure to obtain the natural gas consumption in standard cubic feet per hour.

Part 2. Production energy consumption:

These tests were performed to determine the natural gas consumed by a Surface Combustion Super Allcase integral quench batch furnace (conventional brick insulation) while processing different types of production loads using different atmospheres. Due to the complexity of the piping, four gas meters were required to analyze the natural gas consumed by the furnace. The gas meter arrangement is shown schematically in figure I.

Atmosphere was sampled from the side of the furnace and pumped to analytical equipment consisting of a Carle gas chromatograph, Alnor dew pointer, and Mine Safety infra-red carbon dioxide controller.

ABSTRACT

This second quarterly report details the energy consumption of two heat treating furnaces while employing different atmospheres. Idle energy consumption tests on a box type furnace with a fibrous insulation indicate 7% to 14% lower fuel consumption when pure nitrogen replaces endothermic as a furnace atmosphere.

Production energy consumption tests on an integral quench furnace are inconclusive due to the limited data obtained thus far. As the program progresses, additional data will be available.