Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

October 16, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. Scott Quaas
Environmental Manager
Tarmac America, Inc.
455 Fairway Drive
Deerfield Beach, Florida 33441

RE: NO_X Emissions - Tarmac Kiln No. 2

Dear Mr. Quaas:

This concerns the investigative effort begun by Tarmac over one year ago to determine the reasons for high NO_X emissions from Kiln No. 2 and what can be done about them. KBN's letter of May 28, 1996 stated that Tarmac would conduct tests on a modified coal burner around June 1 and report the results to us within 60 days of test completion. After four months, we have not received any test results.

At some point, the problem will have to be solved by Tarmac or the Department will have to take appropriate action to enforce the existing permit limits. We believe that point should be fast approaching, with the matter being finally resolved one way or the other by the end of this year.

Please give us your immediate assessment of whether the approach currently underway will result in the current NO_X limits being met by early 1997.

If there are any questions regarding the above, please contact John Reynolds or myself at (904)488-1344.

Sincerely,

A. A. Linero 10/16

A. A. Linero, P.E.
Administrator
New Source Review Section

AAL/JR

c: Pat Comer, DEP
Tom Tittle, SED
Ewart Anderson, DCDERM
Brian Beals, EPA
David Buff, KBN

A GOLDER ASSOCIATES COMPANY

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JUN 5 1996
BUREAU OF
AIR REGULATION

June 4, 1996

Mr. A. A. Linero, Administrator
New Source Review Section
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, Fl 32399-2400

Re: Investigation of NO_x Emissions
Tarmac Florida, Kiln No. 2

Dear Mr. Linero:

In KBN's letter dated May 28, to you concerning the above referenced subject, Table A and Kiln 2 NO_x data from 1980 were inadvertently omitted. These are attached for your review. Please call if you have any questions concerning this information.

Sincerely,

David A. Buff

David A. Buff, P.E.
Principal Engineer
Florida P.E. #19011

SEAL

DB/arz

cc: Al Townsend
Scott Quass
Jim Alves

CC: J. Reynolds, BAR

9651002A/2

6241 Northwest 23rd Street Suite 500 Gainesville, Florida 32653-1500 352-336-5600 FAX 352-336-6603

5405 West Cypress Street Suite 215 Tampa, Florida 33607 813-287-1717 FAX 813-287-1716

1801 Clint Moore Road Suite 105 Boca Raton, Florida 33487 407-994-9910 FAX 407-994-9393

7785 Baymeadows Way Suite 105 Jacksonville, Florida 32256 904-739-5600 FAX 904-739-7777

1616 'P' Street NW Suite 350 Washington, DC 20036 202-462-1100 FAX 202-462-2270

TABLE T-2

MIAMI STACK EMISSION SURVEY
NOX EMISSION RATE - EPA METHOD 7

1980

Run No.	Sample No.	Kiln No.	Fuel Type	Date 1980	Lbs. NO_2 / Hr.	Lbs. NO_2 / Ton Clnk.	Lbs. NO_2 / LB.F.Gas	PPM*
1	1	2	Gas	3-20	211.5	9.95	9.45	435
1	2	2	Gas	3-20	109.1	5.13	4.88	224
1	3	2	Gas	3-20	107.4	5.05	4.80	221
1	4	2	Gas	3-20	101.8	4.79	4.55	209
1	5	2	Gas	3-20	96.7	4.55	4.32	199
1	6	2	Gas	3-20	95.4	4.49	4.26	196
1	7	2	Gas	3-20	91.2	4.29	4.08	188
1	8	2	Gas	3-20	57.1	2.69	2.55	117
1	9	2	Gas	3-20	86.5	4.07	3.87	178
1	10	2	Gas	3-20	89.1	4.19	3.98	183
1	11	2	Gas	3-20	124.5	5.86	5.56	256
1	12	2	Gas	3-20	35.6	1.68	1.59	73
	AVE.				100.5	4.73	4.49	207
2	1	2	Oil	3-21	148.0	5.92	7.64	353
2	2	2	Oil	3-21	125.8	5.03	6.50	300
2	3	2	Oil	3-21	147.7	5.91	7.63	352
2	4	2	Oil	3-21	140.8	5.63	7.27	336
2	5	2	Oil	3-21	143.7	5.75	7.42	343
2	6	2	Oil	3-21	267.6	10.70	13.82	638
2	7	2	Oil	3-21	252.6	10.10	13.05	602
2	8	2	Oil	3-21	114.1	4.56	5.89	272
2	9	2	Oil	3-21	81.4	3.26	4.20	194
2	10	2	Oil	3-21	141.3	5.65	7.30	337
2	11	2	Oil	3-21	217.8	8.71	11.25	519
2	12	2	Oil	3-21	233.5	9.34	12.00	557
	AVE				167.9	6.71	8.66	400

Table A. Summary of SO2/NOx Emissions From Kiln No. 2, Tarmac Florida

Date	Run#	Kiln Feed (TPH)	Clinker (TPH)	Coal Usage (TPH)	Heat Input (a) (MMBtu/hr)	Coal Sulfur %	Sulfur Dioxide Emissions ppm	Sulfur Dioxide Emissions lb/hr	Sulfur Dioxide Emissions lb/MMBtu	Sulfur Dioxide Emissions lb/ton kiln feed	Sulfur Dioxide Emissions lb/ton clinker	Nitrogen Dioxide Emissions ppm	Nitrogen Dioxide Emissions lb/hr	Nitrogen Dioxide Emissions lb/MMBtu	Nitrogen Dioxide Emissions lb/ton kiln feed	Nitrogen Dioxide Emissions lb/ton clinker	Oxygen Level (%) Stack	Oxygen Level (%) Kiln	Stack Flow acfm	Stack Flow dscfm
04/26/94	1	39.58	24.08	4.58	114.50	1.86	0.63	0.37	0.003	0.009	0.015	1,187	450	3.93	11.37	18.69			86,415	59,855
04/26/94	2	39.58	24.08	4.58	114.50	1.86	0.61	0.36	0.003	0.009	0.015	1,092	427	3.73	10.79	17.73			91,144	59,855
04/26/94	3	39.58	24.08	4.58	114.50	1.86	0.61	0.35	0.003	0.009	0.015	1,117	422	3.69	10.66	17.52			86,816	57,827
06/28/94	1	38.33	23.6	5.33	133.25	1.75	54.18	32.33	0.243	0.843	1.370	610	255	1.91	6.65	10.81			93,138	59,875
06/28/94	2	38.33	23.6	5.33	133.25	1.75	108.2	62.76	0.471	1.637	2.659	669	281	2.11	7.33	11.91			90,738	58,286
06/28/94	3	38.33	23.6	5.33	133.25	1.75	88.07	51.46	0.386	1.343	2.181	655	282	2.12	7.36	11.95			92,633	58,642
06/28/94	4	38.46	24.0	5.41	135.25	1.75						787	332	2.45	8.63	13.83				58,937
06/28/94	5	38.46	24.0	5.41	135.25	1.75						579	246	1.82	6.40	10.25				59,280
08/31/94	1	32.8	19.3	4.90	122.50	0.85	9.90	5.03	0.041	0.153	0.261	648	237	1.93	7.23	12.28	9.4		78,548	50,967
08/31/94	2	32.8	19.3	4.90	122.50	0.85	20.60	10.89	0.089	0.332	0.564	514	195	1.59	5.95	10.10	9.4		80,268	51,988
08/31/94	3	32.8	19.3	4.90	122.50	0.85	15.00	7.76	0.063	0.237	0.402	488	182	1.49	5.55	9.43	9.4		78,548	50,967
10/27/94	1	38.9	24.7	5.10	127.50	0.76	4.39	2.56	0.020	0.066	0.104	754	316	2.48	8.12	12.79	9.72		115,146	58,456
10/28/94	3	39.8	26.1	5.50	137.50	0.76	3.43	1.96	0.014	0.049	0.075	809	333	2.42	8.37	12.76	9.76		115,912	57,531
10/28/94	4	39.8	26.1	5.50	137.50	0.76	30.52	16.75	0.122	0.421	0.642	544	215	1.56	5.40	8.24	9.28		113,480	55,094
01/03/95	1	40.5	25.0	4.75	118.75	0.88	1.61	0.92	0.008	0.023	0.037	618	255	2.15	6.29	10.19	10.3		91,761	57,583
01/03/95	2	40.5	25.0	4.75	118.75	0.88	1.26	0.7	0.006	0.017	0.028	988	398	3.35	9.84	15.93	10.3		88,956	56,308
01/03/95	3	40.5	25.0	4.75	118.75	0.88	1.23	0.07	0.001	0.002	0.003	883	354	2.98	8.74	14.16	9.76		89,294	56,002
05/31/95	1	38.5	24.0	5.30	132.50	0.67		4.23	0.032	0.110	0.176	923	347	2.62	9.01	14.45	10.7		105,551	52,186
05/31/95	2	38.5	24.0	5.29	132.25	0.67		7.26	0.055	0.189	0.303	883	332	2.51	8.62	13.84	11.1		105,918	51,013
05/31/95	3	38.5	24.0	5.29	132.25	0.67		1.81	0.014	0.047	0.075	821	322	2.43	8.35	13.40	11.2		107,367	53,963
12/11/95	1	35.0	20.8	5.10	127.50		1.51	0.91	0.007	0.026	0.044	728	308	2.42	8.80	14.81	11.0		113,178	59,063
12/11/95	2	35.0	20.8	5.10	127.50		1.53	0.91	0.007	0.026	0.044	824	355	2.78	10.14	17.07	11.3		120,039	60,164
12/11/95	3	35.0	20.8	5.10	127.50		0.00	0.00	0.000	0.000	0.000	1,044	448	3.51	12.80	21.54	10.9		118,322	59,898
						Minimum =	0.00	0.00	0.000	0.000	0.000	488	182	1.49	5.40	8.24	9.28		78,548	50,967
						Average =	19.07	9.97	0.076	0.264	0.429	790	317	2.52	8.37	13.64	10.23		98,246	56,684
						Maximum =	108.16	62.76	0.471	1.637	2.659	1,187	450	3.93	12.80	21.54	11.30		120,039	60,164

(A) Assumes 12,500 Btu/lb coal
NA = Not available

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Scott Quaas, Env. Mgr.
Tarmac America
455 Fairway Dr.
Deerfield Bch, Fl
33441

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P 339 251 169

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PS Form 3811, December 1991 ☆U.S. GPO: 1993—352-714 **DOMESTIC RETURN RECEIPT**

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PS Form 3800, April 1995

A GOLDER ASSOCIATES COMPANY

May 28, 1996

Mr. A. A. Linero, Administrator
New Source Review Section
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, FL 32399-2400

RECEIVED
MAY 30 1996
BUREAU OF
AIR REGULATION

Re: Investigation of NO_x Emissions
Tarmac Florida, Kiln No. 2

Dear Mr. Linero:

As you are aware, Tarmac Florida, Inc., is in the process of investigating the high NO_x emissions being experienced from Kiln 2, and potential methods to reduce the emissions. KBN has been contracted by Tarmac to assist them in this manner. The thrust of our efforts has been toward discovering the reasons for the high emissions, and what can be done to reduce the emissions.

This letter presents a status report to the Department, which presents the results of our efforts to date. In addition, additional time is requested in order to perform stack testing to determine if NO_x reduction measures implemented by Tarmac can result in achieving the permitted NO_x limit, or to what extent they can reduce emissions.

Kiln No. 3 Emissions and Basis for Original BACT

The Department has requested that Tarmac investigate why the NO_x emissions from Kiln No. 2 exceed the BACT limit, and why they are so much higher than Kiln No. 3, which was the basis for the BACT. Therefore, a review of the permitting history of the Kiln No. 2 coal conversion PSD permit is in order.

In the original PSD permit application for the Kiln No. 2 coal conversion, Tarmac proposed BACT levels of 400 lb/hr for SO_2 (16 lb/ton clinker) and 169.3 lb/hr for NO_x (6.77 lb/ton clinker) as starting points for the BACT evaluation. This starting point for NO_x was based on the permitted emission limit for Kiln No. 3, which experience had shown was achievable in Kiln No. 3, as well as a limited set of test data from Kiln No. 2 in 1980 when burning fuel oil and gas (see attached data).

It is also important to note that the proposed BACT control technology was good combustion practices and the inherent SO_2 removal within the kiln system. Due to concerns over the nearby PSD Class I area (Everglades National Park), SO_2 emissions were considered to be of much more importance at the time. Subsequently, EPA agreed that BACT for NO_x was good operating and maintenance procedures to minimize NO_x emissions.

In addition, Tarmac proposed and strongly argued that a comprehensive test program be conducted prior to setting any final emission limits for the kiln. This was due to the uncertainty in emissions from Kiln No. 2 versus Kiln No. 3 (due to different size of the kilns and different firing types). Tarmac alluded to a similar experience with Kiln No. 3 when it was converted to coal. An emission limit was agreed to without any test data, and the limit proved to be unattainable. Therefore, the Kiln No. 3 emission limits were revised. Tarmac did not want to make this same mistake again. Tarmac's commitment was to minimize SO_2 emissions to the extent possible, again due to the Class I area concerns. EPA approved the testing plan as a mechanism to set

6241 Northwest 23rd Street, Suite 500, Gainesville, Florida 32653-1500, 352-336-5600 FAX 352-336-6603
5405 West Cypress Street, Suite 215, Tampa, Florida 33607, 813-287-1717 FAX 813-287-1716
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7785 Baymeadows Way, Suite 105, Jacksonville, Florida 32256, 904-739-5600 FAX 904-739-7777
1616 'P' Street NW, Suite 350, Washington, DC 20036, 202-462-1100 FAX 202-462-2270

the BACT limit for SO_2 in January 1990. The BACT limit for NO_x was also to be set through the testing program.

The actual test data from Kiln No. 2 shows that the original commitment of minimizing SO_2 emissions to the extent practical has been achieved beyond all expectations. The actual SO_2 emissions are well below the allowable BACT limit. However, as will be discussed in this report, the low SO_2 emissions in effect cause the conversely high NO_x emissions.

Kiln No. 2 NO_x Emissions

In Tarmac's February 1996 submittal to the Department, a summary of NO_x test data for Kiln No. 2 as well as other wet process kilns in the U.S. were presented. There was an error presented in Table 1 of this submittal regarding Tarmac's NO_x emissions (emissions were presented in terms of lb/ton kiln feed rather than lb/ton clinker). Therefore, this table is resubmitted (attached).

A complete summary of the SO_2 and NO_x data obtained to date for Kiln No. 2 is presented in Table A attached. As shown, the SO_2 emissions have been very low, while the NO_x emissions have been high compared to the permitted emission rates. The reasons for this have not been fully determined at this time, but according to plant kiln operators, the SO_2 and NO_x emissions are primarily related to the oxygen level in the kiln. They state that as the oxygen level in the kiln increases, SO_2 emissions decrease while NO_x emissions increase. This trend has also been evident on Kiln No. 3. Therefore, KBN is currently analyzing the available test data for Kiln No. 2 to determine if a correlation exists between these parameters.

During the stack tests on Kiln No. 2, oxygen level at the stack is measured. However, this measurement is affected by infiltration of ambient air into the system and is not reflective of conditions in the kiln. Therefore, oxygen levels in the kiln itself are needed. Tarmac maintains a kiln oxygen monitor on Kiln No. 2, and data from this monitor is archived on-site at the plant. KBN is in the process of retrieving these data, but this is a slow process, since the data are contained on strip charts. Once the data is obtained, correlation plots of oxygen versus emissions will be developed.

Based on the information gathered to date for Kiln No. 2, the reasons for the high NO_x emissions can be summarized as follows:

1. Kiln No. 2 operates at a kiln oxygen level normally in the range of 2 to 2.5 percent. By comparison, Kiln No. 3 normally operates at an oxygen level of approximately 1.0 percent.

2. Kiln No. 3 is an indirect fired kiln, meaning that the coal fuel and the primary combustion air are delivered to the kiln separately. This allows more control over the combustion air, allowing the combustion air to be varied to obtain optimum combustion conditions and flame characteristics. The air associated with the coal burner normally is not varied. In a wet process cement kiln, the flame characteristics (flame length and intensity) are critical to clinker production.

   In contrast, Kiln No. 2 is a direct fired kiln, which means that the primary combustion air is delivered to the kiln through the coal feed system. In such a system, the amount of combustion air cannot be reduced or varied, because the air velocity through the burner is critical to the flame characteristics.

3. This difference in the two kilns is reflected in the gas flow rates from the kilns. Kiln No. 2, with a maximum clinker production rate of 25 TPH, has a exhaust gas flow rate of 50,000 to 60,000 dscfm. This equates to 120,000 to 144,000 dscfm per ton of clinker produced. Kiln No. 3 normally operates at 87.5 TPH clinker with exhaust gas flow of 140,000 to 160,000 dscfm. This equates to 96,000 to 99,000 dscfm per ton of clinker produced. Therefore, Kiln No. 2 requires approximately 25 percent to 45 percent more air to operate than Kiln No. 3. This in turn results in a higher oxygen level in the kiln, and hence higher NO_x emissions but lower SO_2 emissions compared to Kiln No. 3.

Measures to Reduce NO_x Emissions in Kiln No. 2

Based on the above discussion, Tarmac is focusing on reducing the amount of combustion air to the kiln as the only feasible means of lowering NO_x emissions. To this end, Tarmac recently installed a modified coal burner on Kiln No. 2 during a recent outage in April. The previous coal burner had a 13 inch nozzle, while the new burner will have a 10 inch nozzle. The intention in reducing the nozzle diameter is to reduce the amount of primary air introduced through the coal burner, while maintaining the velocity through the burner obtained by the previous burner design, thus maintaining the previous flame characteristics. The test will also be used to determine the effects of the changes upon the grindability of the clinker product. As discussed above, proper clinker production is dependent upon the flame characteristics.

Tarmac is planning on conducting stack testing on Kiln No. 2 with the new burner in late May or early June. This test will assess the effectiveness and potential in reducing NO_x emissions from Kiln No. 2. The Department will be notified prior to the testing as to the exact test dates. Upon completion of the testing, the test data will be analyzed and submitted to the Department. This analysis, along with analysis of the historic test data as described above, will be submitted to the Department within 60 days of completing the testing.

The current construction permit for Kiln No. 2 has an expiration date of May 31, 1996. However, since Tarmac is a Title V source, it is our understanding that this construction permit is automatically extended to the later of November 1, 1996, or 240 days after commencing operation, per Rule 62-213.420(1)(a)4.

Please call if you have any questions concerning this information or the attached report.

Sincerely,

David A. Buff

David A. Buff, P.E.
Principal Engineer
Florida P.E. #19011

SEAL

DB/arz

cc: Al Townsend
Scott Quass
Jim Alves
File (2)

CC: John Reynolds, BAR
EPA
NPS

9651002A/1

Table 1 Summary of Nitrogen Oxide Emissions from Coal-Fired Wet Process Cement Kilns (Revised 5/28/96)

Source of Emission Factor	Fuel	Type of Firing	No. of Source Tests or CEM Data	Reference	Heat Input Rate (lb/MMBtu)	Clinker Production Rate (tons/hr)	NOx Emissions lb/hr Average	NOx Emissions lb/hr Range	NOx Emissions lb/MMBtu Average	NOx Emissions lb/MMBtu Range	NOx Emissions lb/ton clinker Average	NOx Emissions lb/ton clinker Range
Tarmac Kiln 2 NOx Limit	Coal	Direct	1	1	162 5	25	--	113 8, max	--	0 70, max	--	4 55, max
Tarmac Kiln 3 NOx Limit	Coal	Indirect	1	1	417.5	88	--	592, max	--	1 42, max	--	6 77, max
Tarmac Source Tests No 2 Kiln, 1994 and 1995	Coal	Direct	6	2	115-138	19-26	308 8	205 - 417	2 50	1 7 - 3.8	13 1	8 2 - 18 7
Tarmac Source Tests No 3 Kiln, 1982 thru 1993	Coal	Indirect	16	3	360-473	79-92	533 0	218 - 855	1.34	0 7 - 2.1	6 2	3 5 - 8.8
Rinker Source Tests 2 Kilns	Coal	Direct	3	4	352 4	71 4	1,182 3	883 - 1431	3.36	2 5 - 4 1	16.6	12 3 - 20 1
1982 PCA Survey of Coal-fired Wet Process Cement Kilns (b)	Coal	-	8	5	--	--	--	--	--	--	5 0	1 7 - 8.3
Continental Cement Company June 20, 1990	Coal	Direct	1	6	475 0 (a)	57 0	671 6	--	1 41	--	--	--
Holnam, Inc CEM Data: July 16, 1992	Coal	Direct	1	7	--	--	--	--	--	--	12 50	--
Holnam, Inc Source Test: October 24, 1991	Coal	Direct	1	8	--	--	--	--	--	--	5 80	--
Lehigh Portland Cement Company Source Test May 22, 1990	Coal	Direct	1	9	162 5	--	--	--	1 12	--	5 90	--
AVERAGE							**673.9**		**1.9**		**9.3**	
RANGE							**(309 - 1,182)**		**(1.1 - 3.4)**		**(5.0 - 16.6)**	

Footnotes

(a) Heat Input (Btu/hr) is based on burning 100% coal, and any supplemental fuel is added at a rate of 50% of the coal Btu load (i e 50% coal Btu/hr, 50% hazardous waste Btu/hr)

(b) Emissions are based on a study of 8 wet process cement kilns firing 100% coal

References

1 From Permit Allowables for Kiln 2 (AC13-169901 ,PSD-FL-142), and for Kiln 3

2. Tarmac Source Tests - No 2 Kiln: April 26-27, 1994, June 28-29 1994, August 31, 1994, October 27-28, 1994, January 3, 1995, and May 31, 1995, Medley, Florida

3 Tarmac Source Tests - No 3 Kiln, April and May 1982, May 16, 24, 31, and August 1985, December 1986, April and December 1987, July and August 1988, May and August 1989, October 1990, August 1992, and September 1993, Medley, Florida

4 Rinker Materials Corporation Source Tests January 1993; Dade County, Florida Fired with 100% Coal.

5 "An Overview of the Formation of SOx and NOx in Various Pyroprocessing Systems" by Peter Bechtoft Nielsen & Ove Lars Jepsen, F L Smidth & Co A/S, Copenhagen, Denmark Figure 8 1

6 "Emissions Testing of a Wet Cement Kiln at Hannibal, Missouri Draft Final Report " EPA-530-SW-91-017, Continental Cement Company Source Test June 20, 1990, Hannibal, Missouri Fired with 100% Coal

7 "Alternative Control Techniques Document-NOx Emissions from Cement Manufacturing " EPA-453/R-94-004 Holnam, Inc CEM Data July 16 1992, Artesia, Mississippi Fired with 100% Coal

8 "Alternative Control Techniques Document-NOx Emissions from Cement Manufacturing " EPA-453/R-94-004 Holnam Inc, Source Test, October 24, 1991, Florence, Colorado Fired with 100% Coal

9 "Alternative Control Techinques Document-NOx Emissions from Cement Manufacturing " EPA-453/R-94-004 Lehigh Portland Cement Company Source Test, May 22, 1990, Cementon, New York Fired with 100% Coal

February 16, 1996

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AIR REGULATION

Mr. A.A. Linero, Administrator
New Source Review Section
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, Fl 32399-2400

Re: Investigation of NO_x Emissions
Tarmac Florida, Kiln No. 2

Dear Mr. Linero:

The attached report presents the results of a literature search and survey conducted by KBN Engineering and Applied Sciences, Inc. (KBN) on behalf of Tarmac Florida, Inc. This report is the result of work efforts on Task 1 as described in an October 3, 1995, letter from Jim Alves of Hopping, Green, Sams & Smith to the Department. It is part of Tarmac's ongoing investigation into the high NO_x emissions being experienced from Kiln 2, and potential methods to reduce the emissions.

This report has been delayed from the originally intended date due to a number of reasons, including the Christmas holidays, the EPA shutdown in December and early January, and staff vacations and emergency leave. The report presents a summary of the data gathered by KBN to date. Our data gathering and research efforts on this subject are continuing.

Please call if you have any questions concerning this information or the attached report.

Sincerely,

David A. Buff

David A. Buff, P.E.
Principal Engineer

DAB/lcb

cc: Al Townsend
Scott Quass
Jim Alves
File (2)

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KBN ENGINEERING AND APPLIED SCIENCES, INC.

6241 Northwest 23rd Street, Suite 500, Gainesville, Florida 32653-1500, 352 336 5600 FAX 352 336-6603
5405 West Cypress Street, Suite 215, Tampa, Florida 33607, 813 287 1717 FAX 813 287-1716
1801 Clint Moore Road, Suite 105, Boca Raton, Florida 33487, 407 994 9910, FAX 407 994 9393
7785 Baymeadows Way, Suite 105, Jacksonville, Florida 32256, 904-739 5600 FAX 904 739 7777
1615 P Street NW, Suite 350, Washington DC 20036, 202 462 1100, FAX 202 462 2270

TARMAC FLORIDA, INC.
DEERFIELD BEACH, FL

NITROGEN OXIDE EMISSIONS AND REDUCTION FROM WET PROCESS CEMENT KILNS

LITERATURE SEARCH

KBN Engineering and Applied Sciences, Inc. (KBN) performed an extensive literature search to determine available information on reducing nitrogen oxide (NO_x) emissions from wet process cement. The following sources were contacted to obtain emissions information:

- U.S. Environmental Protection Agency (EPA) Research Triangle Park
- Best Available Control Technology/Lowest Achievable Emission Rate (BACT/LAER) Clearinghouse
- State of California
- Portland Cement Association
- Air Pollutant Control Equipment Vendors
- Suppliers of Coal Burners
- Current Operators of Wet Process Cement Kilns

Refer to the tables in Attachment A for a detailed listing of all sources contacted and the results of each contact. The literature review and information survey focused on actual NO_x emissions from wet process cement kilns, and control techniques employed to reduce NO_x emissions. It is noted that the literature search is ongoing, and additional information is expected to be obtained in the near future.

FACTORS WHICH AFFECT NO_X EMISSIONS

The literature review yielded several pertinent articles related to the formation of NO_x emissions in wet process cement kilns and the factors which affect these emissions. For long, wet kilns which fire only coal, such as Tarmac Kiln 2, the following factors were identified:

1. In wet process kilns firing coal only, the single fuel combustion zone and high temperature required to complete the clinker formation process (2,750°F) lead to high thermal NO_x formation. The major factors are combustion zone temperature,

residence time of combustion gases at the high temperature, the oxygen level in the kiln, and ratio of primary combustion air to secondary air.

2. Energy efficiency of the process is a factor, since a higher heat input requires higher combustion air amounts, leads to higher temperatures, etc.
3. Gas-fired NO_x emissions are generally higher than coal-fired emissions, due to a shorter, more intense flame associated with gas firing (other factors being equal).
4. *Direct firing* is the term used when the primary combustion air is the air swept through the coal mill to deliver the coal to the burner. In *indirect firing*, the primary combustion air is supplied to the kiln independent of the coal supply. Thus, in direct fired kilns, the amount of primary air is large and cannot be adjusted much due to the need to supply the necessary amount of coal at the proper velocity at the burner. In indirect firing systems, the amount of primary air supplied with the fuel is relatively small; therefore, the secondary air amount is higher and can be varied. For these reasons, direct fired kilns generally have higher NO_x emissions than indirect fired kilns.
5. Increasing excess air to the kiln will increase NO_x emissions up to a point, then will decrease emissions due to the reduction in flame temperature. Generally, oxygen levels of 4 to 5 percent result in high NO_x emissions, whereas oxygen levels of 0.5 to 1.5 percent produce low emissions.
6. Coal nitrogen content potentially affects total NO_x emissions: a typical kiln with a heat rating of 5.3 million British thermal units per ton (MMBtu/ton) clinker using a coal with a nitrogen content of 1 percent has the potential to produce fuel NO_x emissions of up to 14.5 pounds per ton (lb/ton) clinker.
7. The nitrogen content of the raw feed is a potential source of NO_x. Raw feed nitrogen levels have been found to vary from 20 to 1,000 parts per million (ppm). A raw feed content of 100 ppm has the potential to produce NO_x emissions up to 1 lb/ton clinker.
8. Other factors which affect wet process cement kiln NO_x emissions include the burnability of the raw feed and sulfur dioxide (SO_2) control employed.

NO_x EMISSIONS FROM WET PROCESS CEMENT KILNS

Based upon information obtained during the literature search and information survey, a compilation of NO_x emissions from wet process coal-fired cement kilns was developed. A summary of this information obtained to date is presented in Tables 1 and 2.

A summary of the NO_x data obtained for coal-only fired wet process kilns is presented in Table 1. Table 2 lists kilns which fire a mixture of coal and other fuels such as waste tires or petroleum coke. Included in Table 1 are Tarmac's present permit limits for Kilns 2 and 3, as well as actual source test data from these kilns. Also included are the test data from Rinker's two wet process kilns, also located in south Florida. As shown, the NO_x emissions data show wide variation, from 4.6 to 17.7 lb/ton clinker produced (average for a kiln). Actual emissions from Tarmac Kiln 2 fall in the lower range of these data at 8.1 lb/ton clinker (average). The average NO_x emission factor from AP-42, Section 11.6, Portland Cement Manufacturing, is 7.4 lb/ton clinker.

CONTROL TECHNIQUES FOR NO_x EMISSIONS

Thermal NO_x dominates NO_x formation in wet process cement kilns. As a result, NO_x emissions from wet process cement kilns can be controlled by two primary methods: combustion techniques and post-combustion technologies. Combustion control technologies are used to modify combustion conditions to reduce flame temperature and available oxygen, and to stage the combustion.

For direct-fired kilns, indirect firing has the potential to reduce NO_x emissions by reducing the available oxygen and staging the combustion, but this reduction must be weighed against the cost of converting and the environmental benefits.

Limited information is available regarding the use of low NO_x burners or flue gas recirculation in cement kilns. Direct fired kilns must be converted to indirect firing prior to use of low NO_x burners.

Post-combustion control technologies for NO_x reduce emissions after they are formed. These methods include: selective non-catalytic reduction (SNCR) and selective catalytic reduction (SCR). SNCR is not considered applicable to wet kilns due to difficulties involved in continuous injection of reducing agents. SCR has not been demonstrated on cement kilns and, therefore, is not considered to be applicable at this time.

The South Coast Air Quality Management District (SCAQMD) has adopted cement kiln best available control technology (BACT) guidelines; however, they do not include wet process cement kilns. The Bay Area Air Quality Management District (BAAQMD) has developed BACT guidance for precalciner kiln systems, not wet process kilns.

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