AP-42 Section 10.8
Reference 16
Report Sect. 4
Reference 16

CALCULATED EMISSIONS

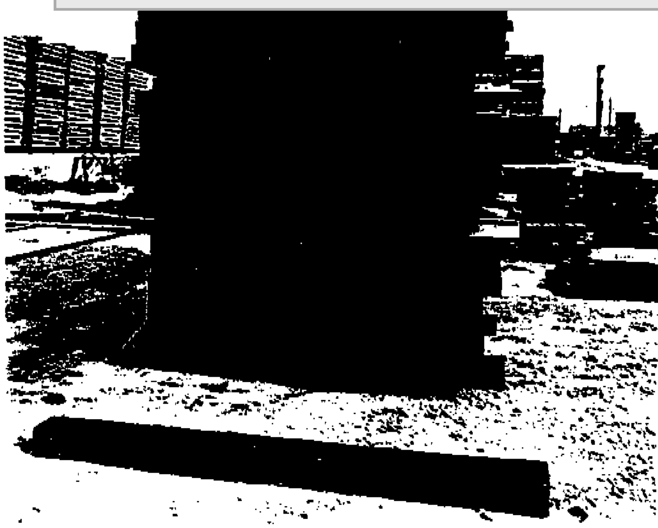
FROM

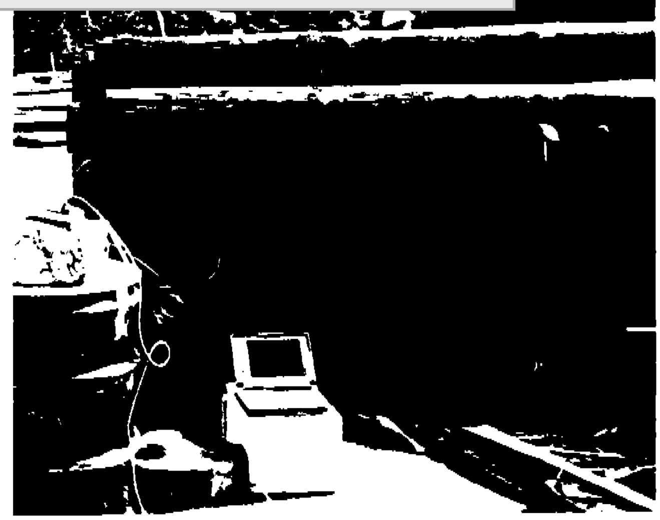
CREOSOTE-TREATED WOOD PRODUCTS

(CROSS-TIES and POLES)

Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.





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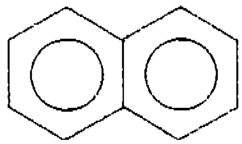
Brentwood, Tennessee

American Wood Preservers Institute

Vienna, Virginia

OCTOBER 13, 1994

optimizing environmental resources - water, air, earth



STRUCTURE

$C_{10}H_8$

CAS No:	**91-20-3**
Molecular Weight:	**128.18 lb/lbmole**
Boiling Point:	**218 °C**
Vapor Pressure	**0.2762 mm Hg at 25 °C**
Henry's Law Constant	**43.01 Pa m^3/mol at 25 °C**
Specific Gravity:	**1.1131 g/cm^3 at 20 °C**
Water Solubility:	**31 mg/L at 25 °C**
Log Octanol/Water Coefficient:	**3.37**
K_{OW}:	**2,344**

CHEMICAL PROPERTIES OF NAPHTHALENE

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FACTORS AFFECTING EMISSIONS

- FINAL VACUUM and/or SWEEP TIME
- NUMBER OF TIES
- AGE OF TIES
- TEMPERATURE and VAPOR PRESSURE
- STACKING GEOMETRY
- SURFACE AREA
- WIND VELOCITY and HUMIDITY*

* Not taken into account at this time.

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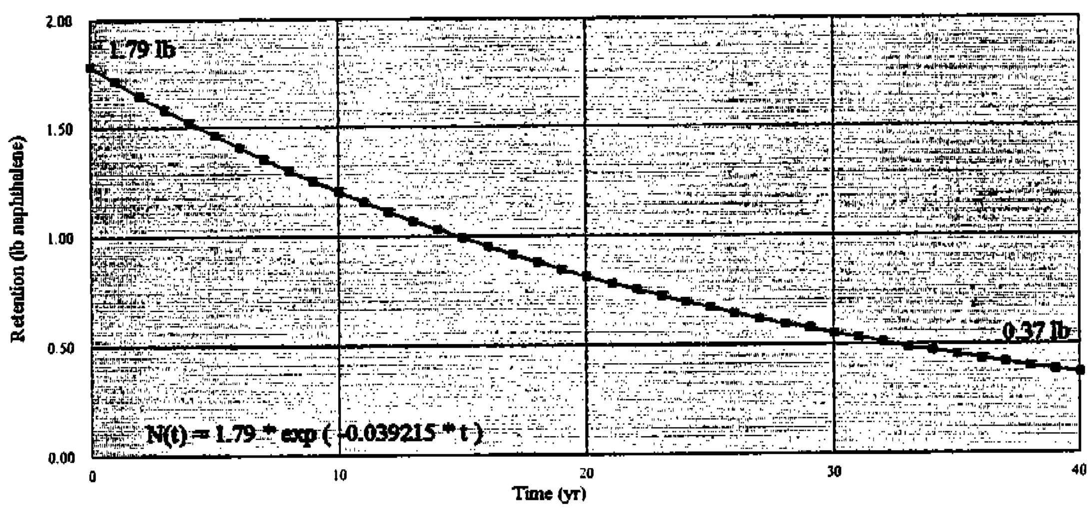
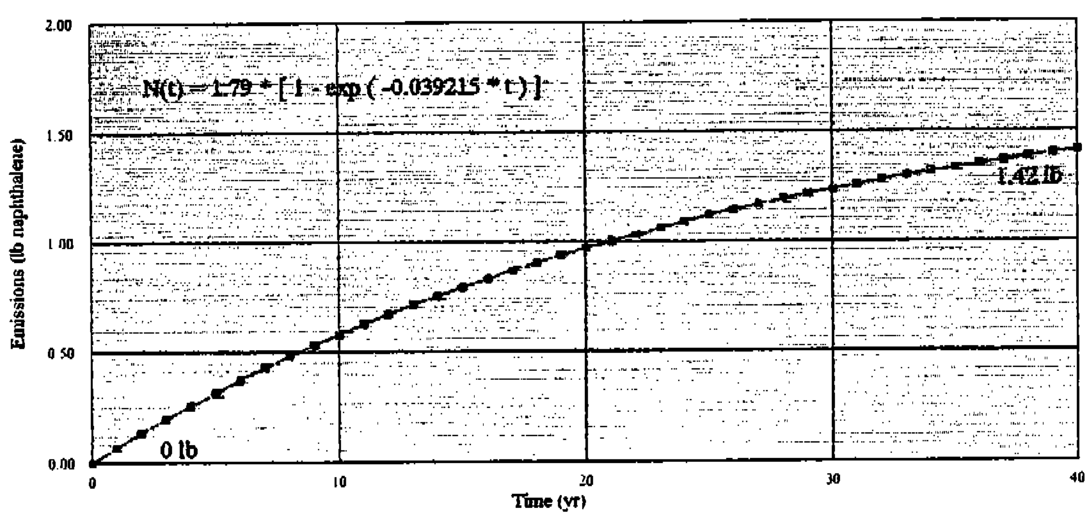
EXAMPLE NAPHTHALENE RETENTION AND EMISSION CURVES FOR BLACK TIES

Basis and Assumptions		
Basis	3.72	cu. ft of treated wood (one 7" x 9" x 8.5' tie)
Creosote Retention	8.0	lb creosote/cu. ft of wood
Percent Naphthalene in Creosote	6.0	%
Initial Naphthalene Retention	1.79	lb naphthalene
Life of Tie	40	yr
Naphthalene Retained @ End of Life 70%	0.37	lb
General First-Order Equation		N(t) = No * exp[-k * t]
		N(t) = lb naphthalene
		t = years
Emission Rate, k	0.000107	1/day
	0.039215	1/year
Retention Equation Under These Conditions		**N(t) = 1.79 * exp (-0.039215 * t)**
		N(t) = lb naphthalene retained
		t = years
Emission Equation Under These Conditions		N(t) = 1.79 * [1 - exp (-0.039215 * t)]
		N(t) = lb naphthalene emitted
		t = years

CUMULATIVE NAPHTHALENE RETENTION IN BLACK TIES



CUMULATIVE NAPHTHALENE EMISSIONS FROM BLACK TIES



VARIATION OF NAPHTHALENE VAPOR PRESSURE WITH TEMPERATURE

Source: Perry's Chemical Engineer's Handbook, 6th Ed.

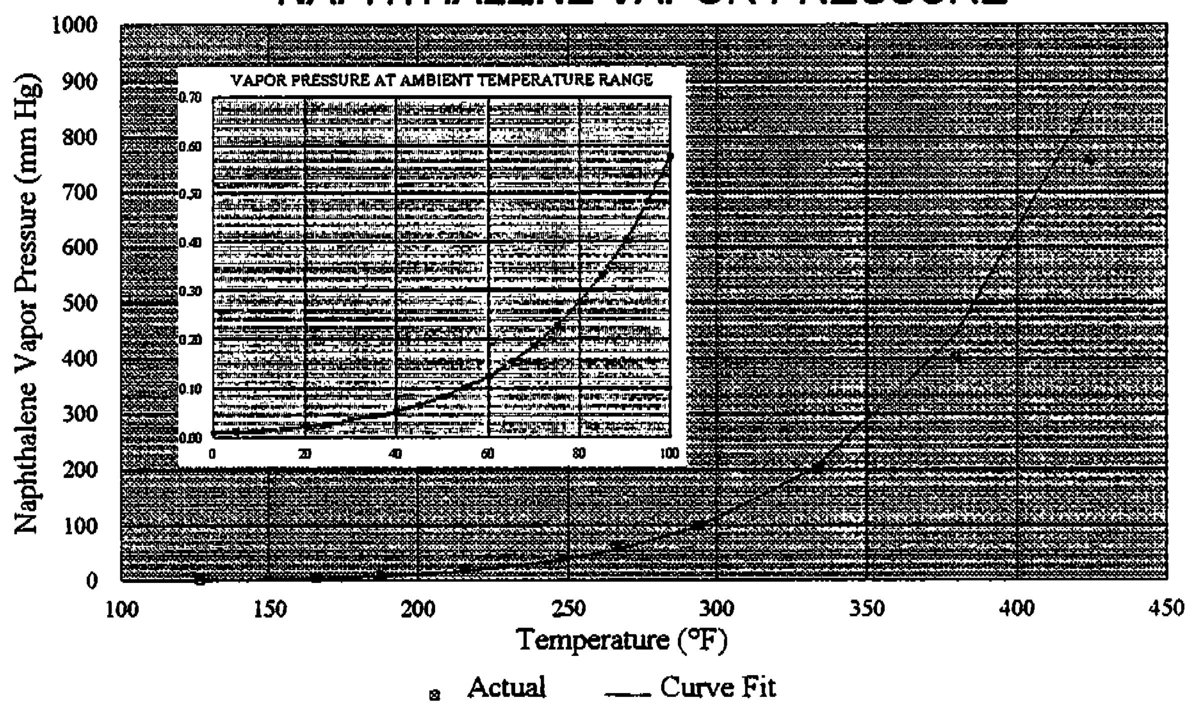
Temperature °C	Temperature °F	VP (mm Hg)	1/Temp (1/R)	ln(VP)	Calc. VP (mm Hg)	% Diff.
52.6	126.68	1	0.001705	0.000000	1.4	43.0
74.2	165.56	5	0.001599	1.609438	4.7	-6.7
85.8	186.44	10	0.001547	2.302585	8.3	-17.0
101.7	215.06	20	0.001481	2.995732	17.3	-13.7
119.3	246.74	40	0.001415	3.688879	36.2	-9.5
130.2	266.36	60	0.001377	4.094345	55.5	-7.5
145.5	293.90	100	0.001326	4.605170	97.3	-2.7
167.7	333.86	200	0.001260	5.298317	204.9	2.5
193.2	379.76	400	0.001191	5.991465	441.9	10.5
217.9	424.22	760	0.001131	6.633318	862.2	13.4

Regression Output:

Constant		19.38216
Std Err of Y Est		0.170405
R Squared		0.993869
No. of Observations		10
Degrees of Freedom		8
X Coefficient(s)	-11161.25	
Std Err of Coef.	309.9363	

VP (mm Hg) = 2.616E+08 * exp [-11161.25 /(T, °F + 460)]

NAPHTHALENE VAPOR PRESSURE



FIELD DATA

- MEASUREMENTS INDICATE THREE RATES OF DECAY GOVERNED BY THREE EQUATIONS
  - TEMPERATURE-RISE EMISSIONS (MAXIMUM EMISSION RATES)
  - THIN- FILM EMISSIONS (FAST EMISSION RATES)
  - PORE-SPACE EMISSIONS (SLOW EMISSION RATES)

- EMISSION MEASUREMENTS WERE MADE FROM CREOSOTE-TREATED POLES

- EMISSIONS WERE MEASURED AT AMBIENT CONDITIONS IN CALIFORNIA

- DATA SUGGEST THAT NAPHTHALENE IS LOST AT AN INCREASED RATE DURING THE FIRST 24 HOURS AFTER THE TREATED WOOD IS TAKEN FROM THE RETORT

- TEMPERATURE DATA OF FRESHLY TREATED WOOD WERE TAKEN FOR BLCK TIES AT KERR-McGEE FACILITIES IN AVOCA, PENNSYLVANIA AND INDIANAPOLIS, INDIANA, AND FOR POLES AT THE KOPPERS FACILITY IN GRENDA, MISSISSIPPI

- EMISSION RATES CLOSELY FOLLOW THE TEMPERATURE OF THE THE TREATED WOOD

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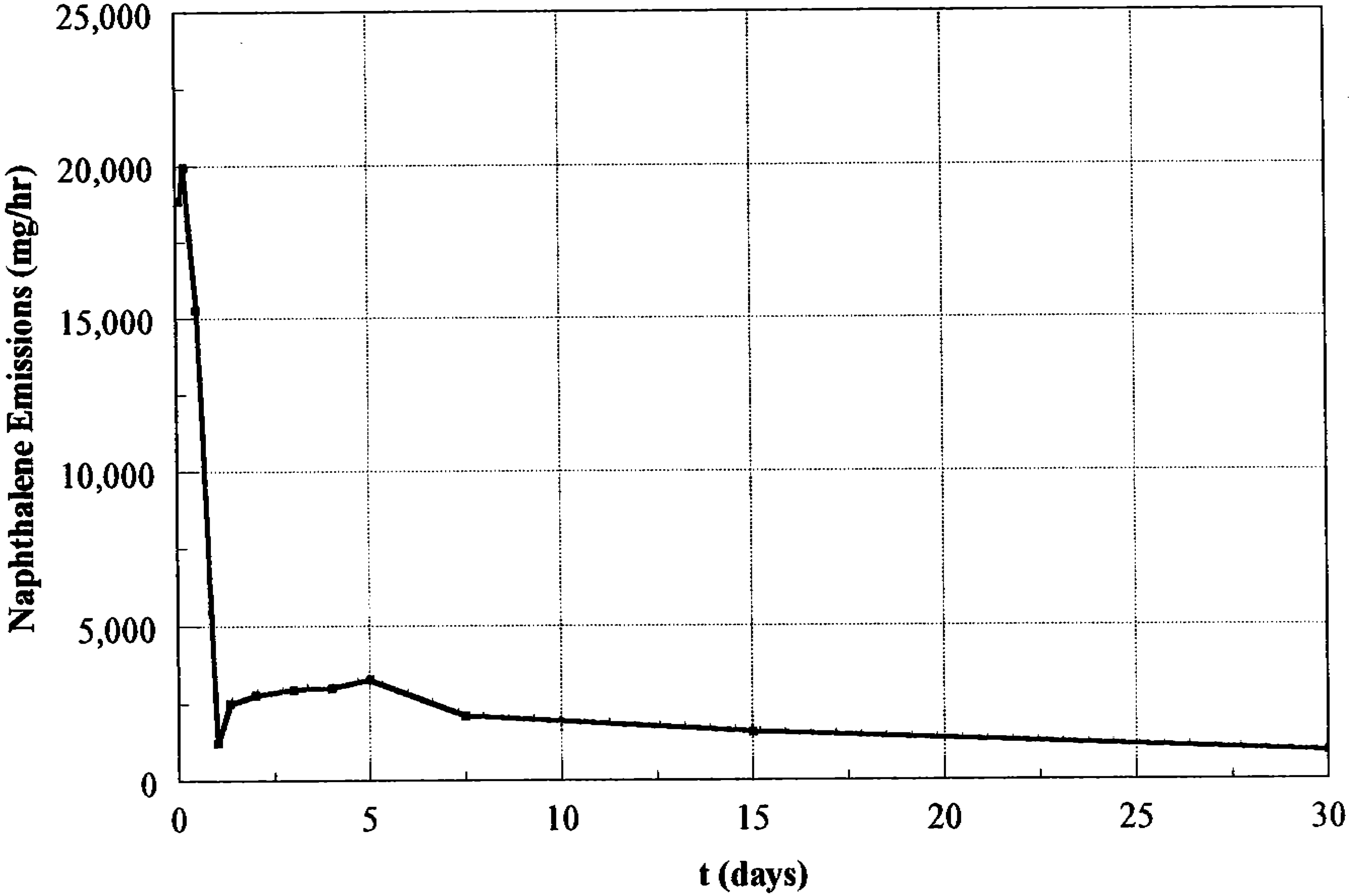
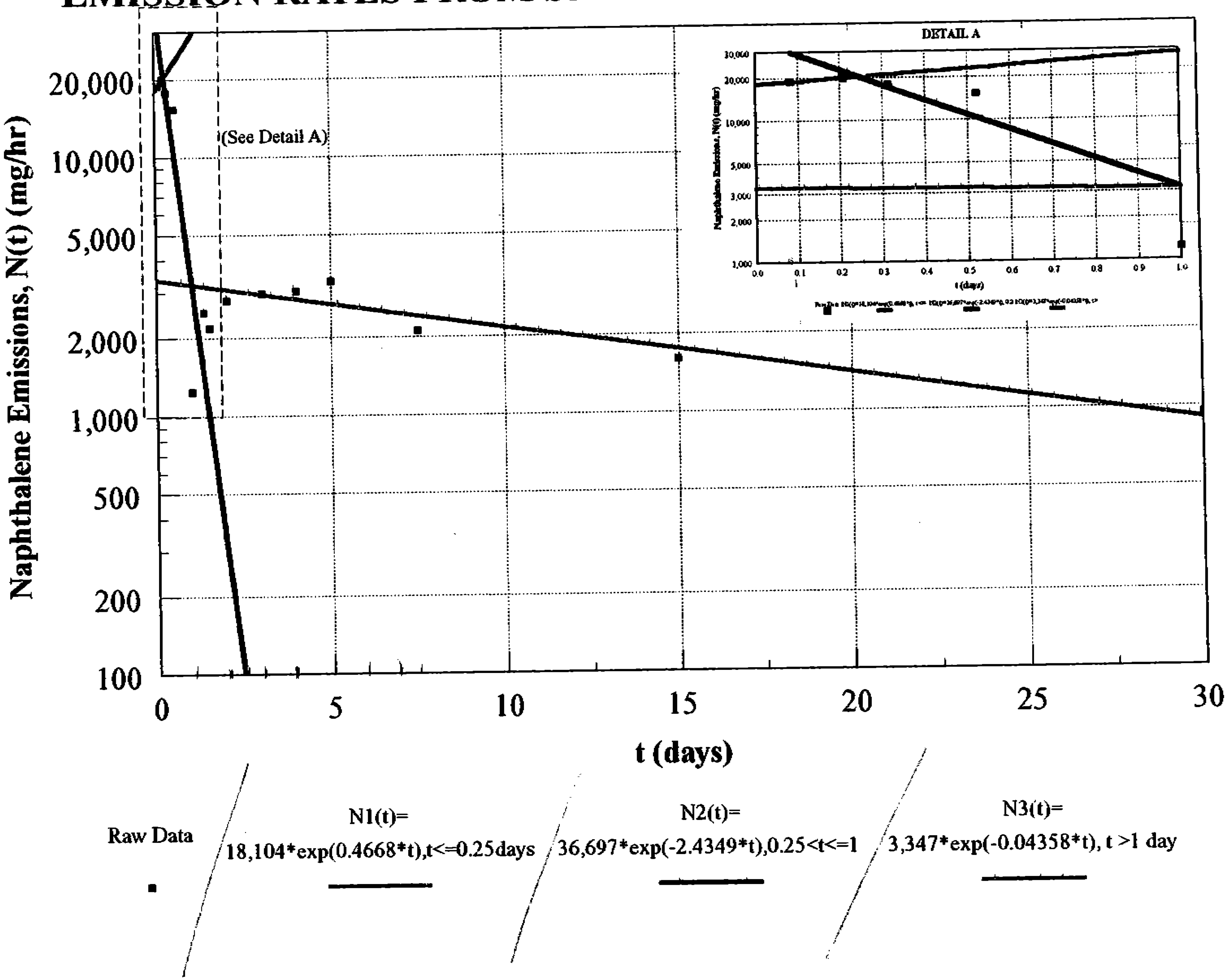
EMISSION RATES FROM CREOSOTE-TREATED POLES

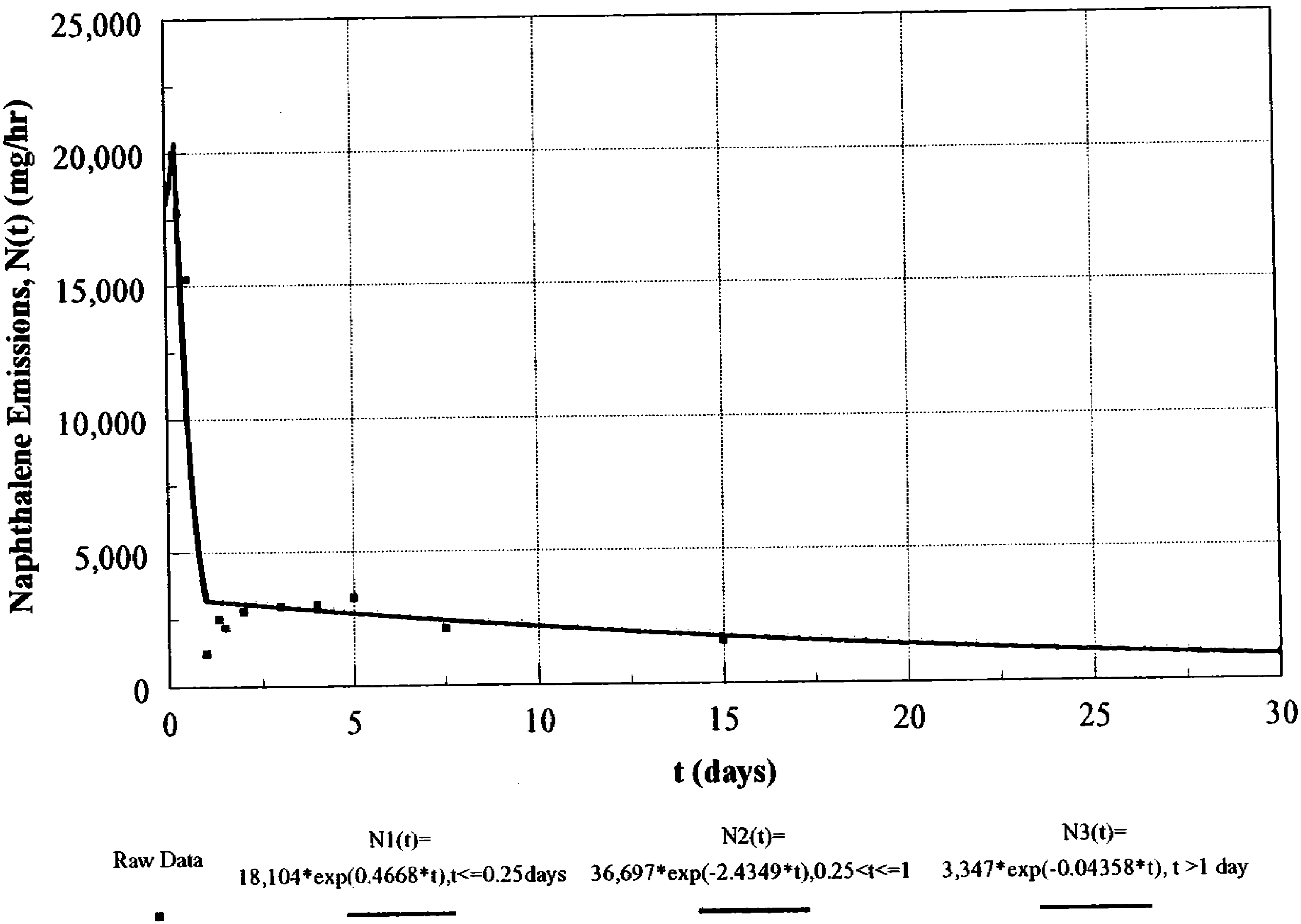
RAW DATA

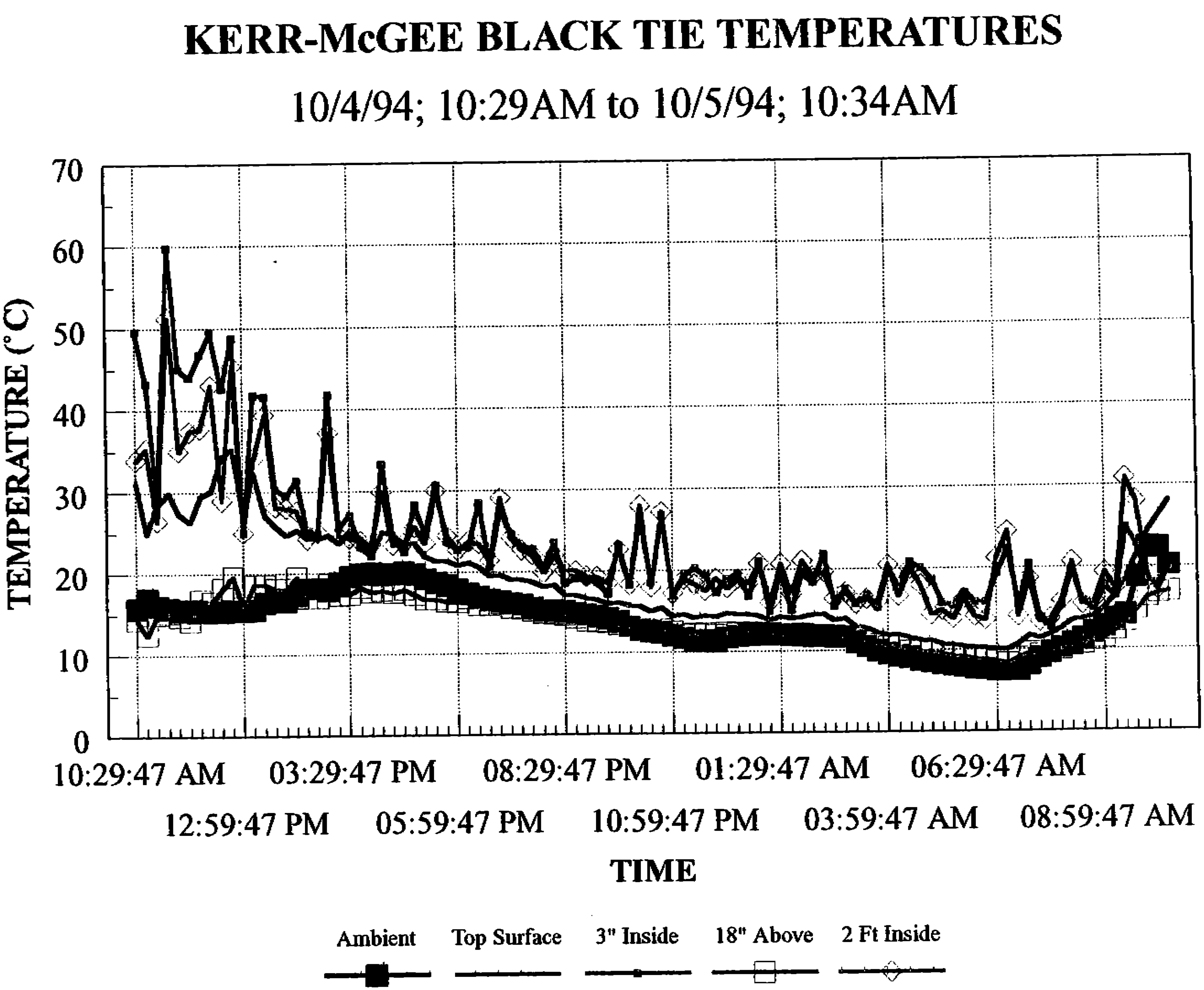


EMISSION RATES FROM SIX CREOSOTE-TREATED POLES



EMISSION RATES FROM SIX CREOSOTE-TREATED POLES

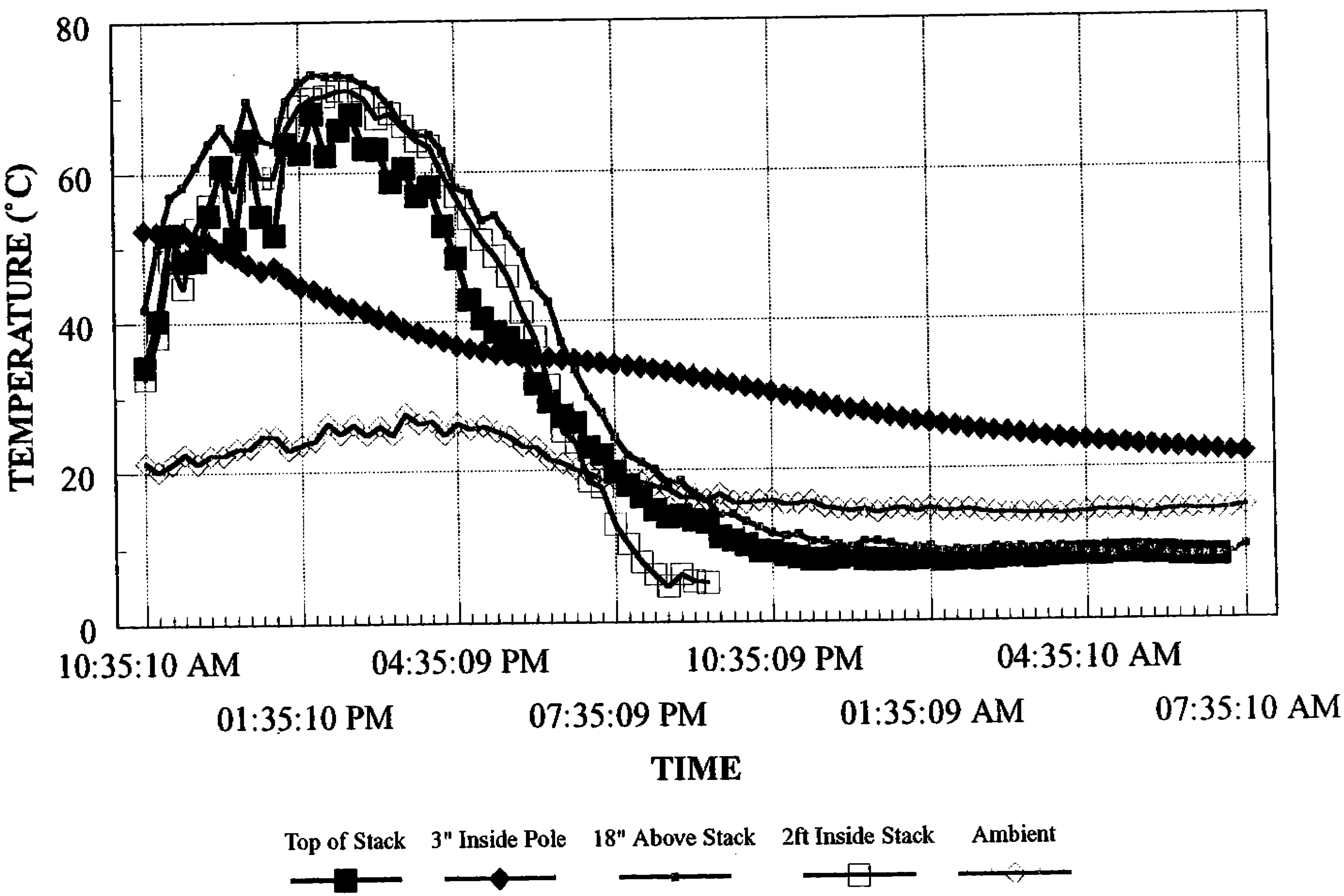




KERR-McGEE BLACK TIE TEMPERATURES
10/4/94; 10:29AM to 10/5/94; 10:34AM
TEMPERATURE (°C)
70
60
50
40
30
20
10
0
10:29:47 AM
12:59:47 PM
03:29:47 PM
05:59:47 PM
08:29:47 PM
10:59:47 PM
01:29:47 AM
03:59:47 AM
06:29:47 AM
08:59:47 AM
TIME
Ambient
Top Surface
3" Inside
18" Above
2 Ft Inside

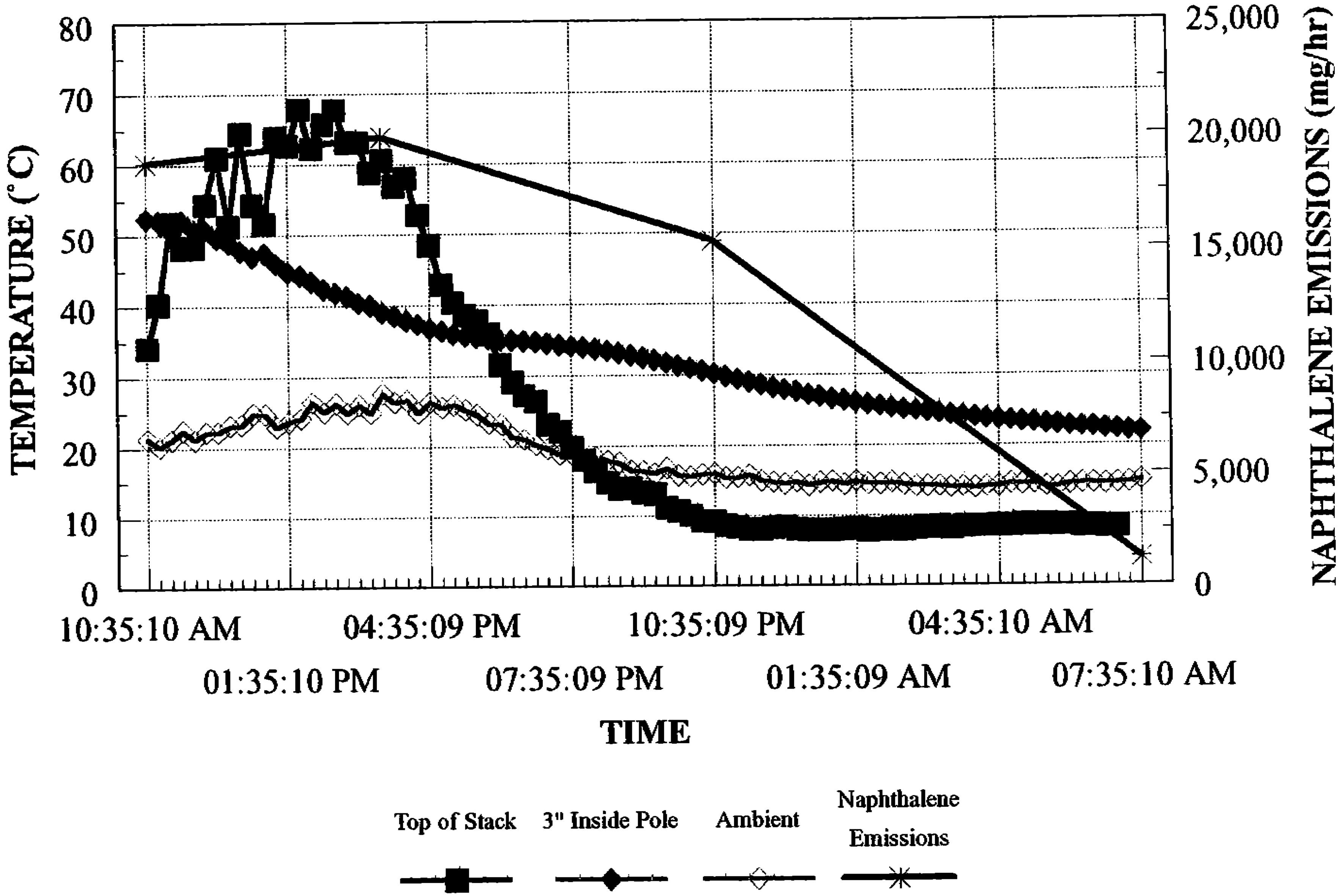
KOPPERS POLE TEMPERATURE MEASUREMENTS

Sept 27, 94 10:35AM to Sept 28,94 2:30PM

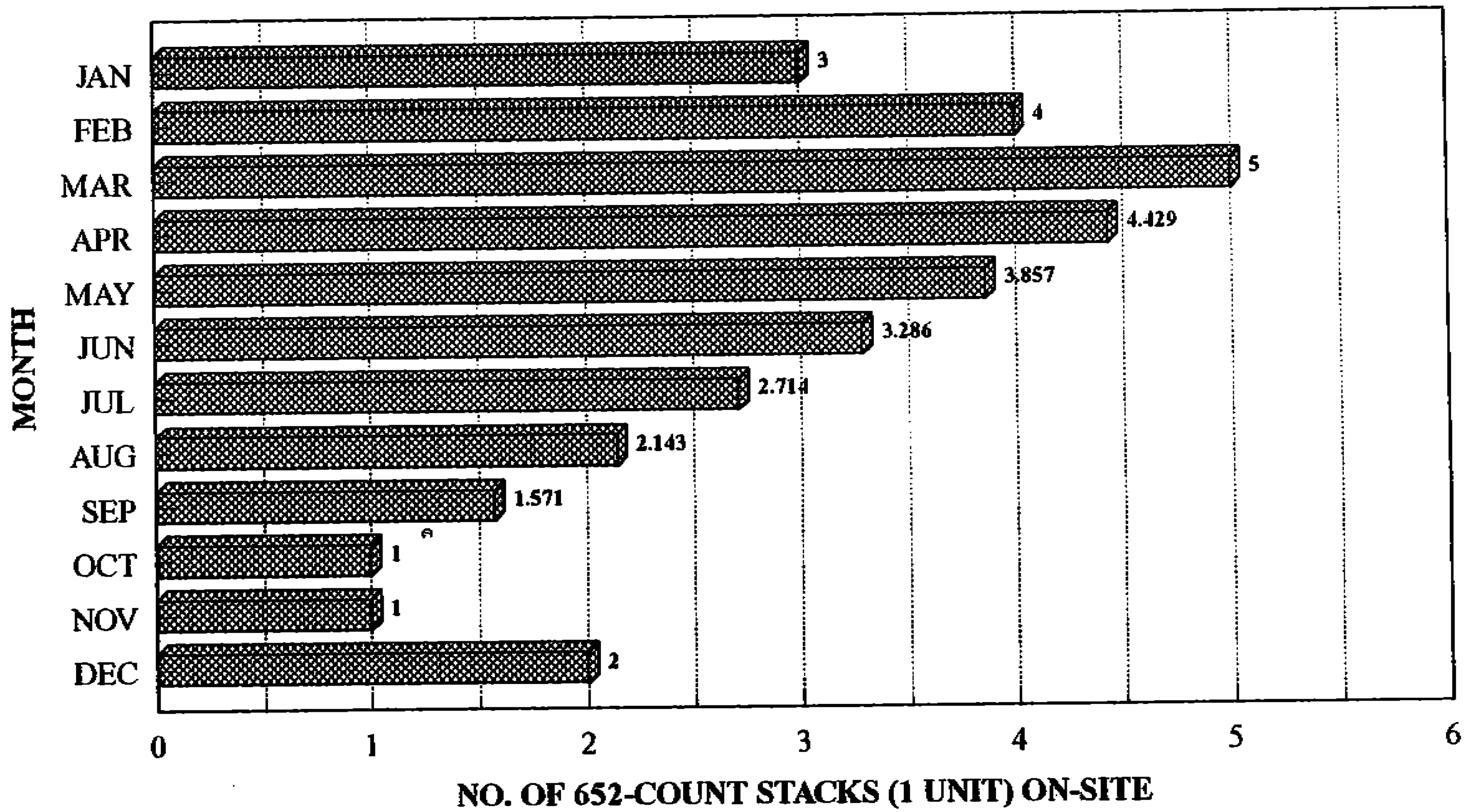


KOPPERS POLE TEMPERATURE MEASUREMENTS

Sept 27, 94 10:35AM to Sept 28,94 2:30PM



STORAGE DISTRIBUTION FOR BLACK TIE STORAGE YARD



Treated Ties Stored On-Site

Maximum 469,440

Minumum 93,888

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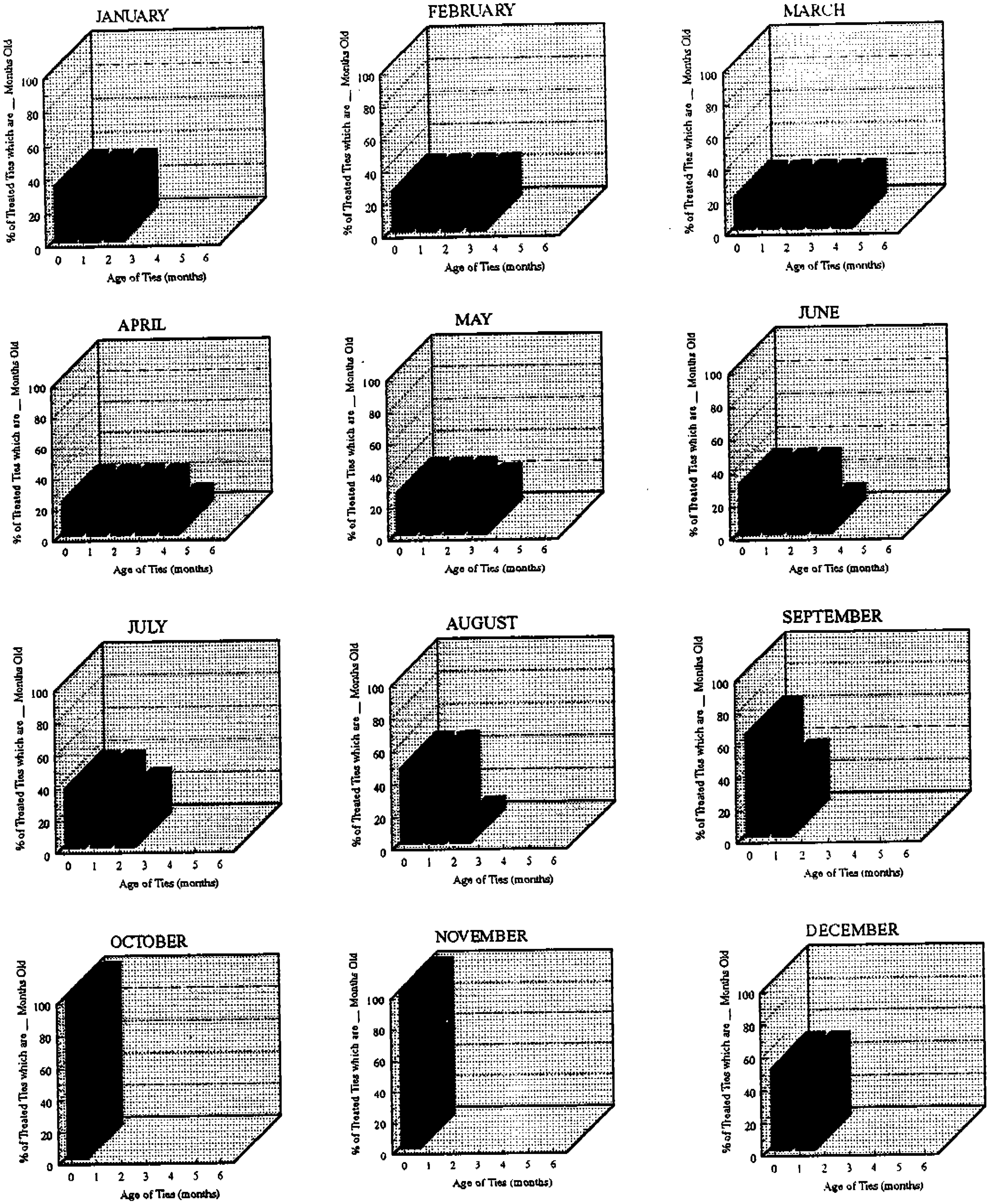

BLACK TIE STORAGE YARD AGE DISTRIBUTION

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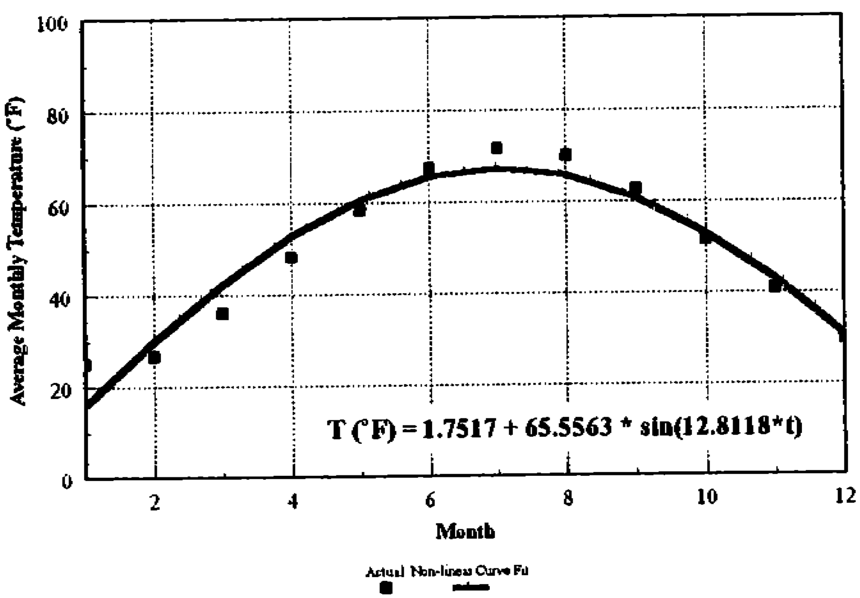
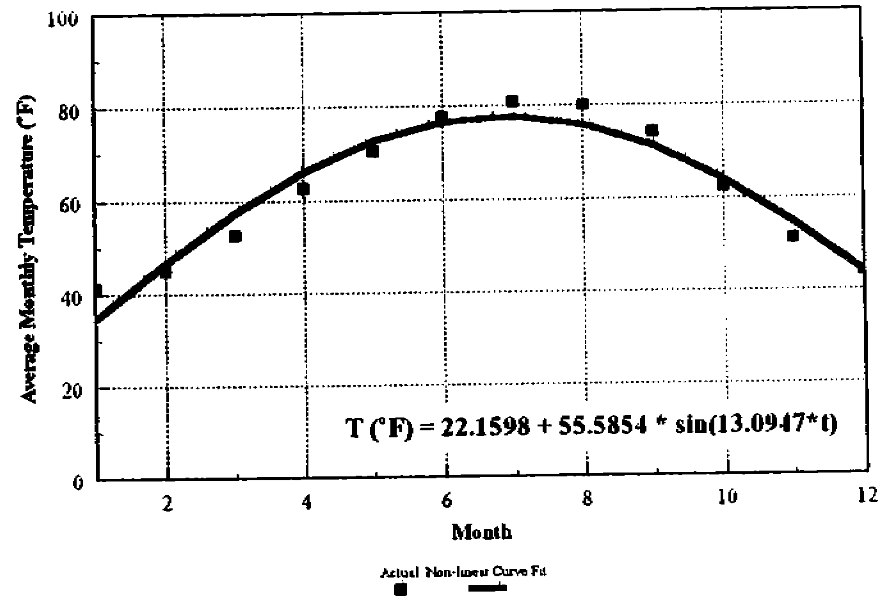
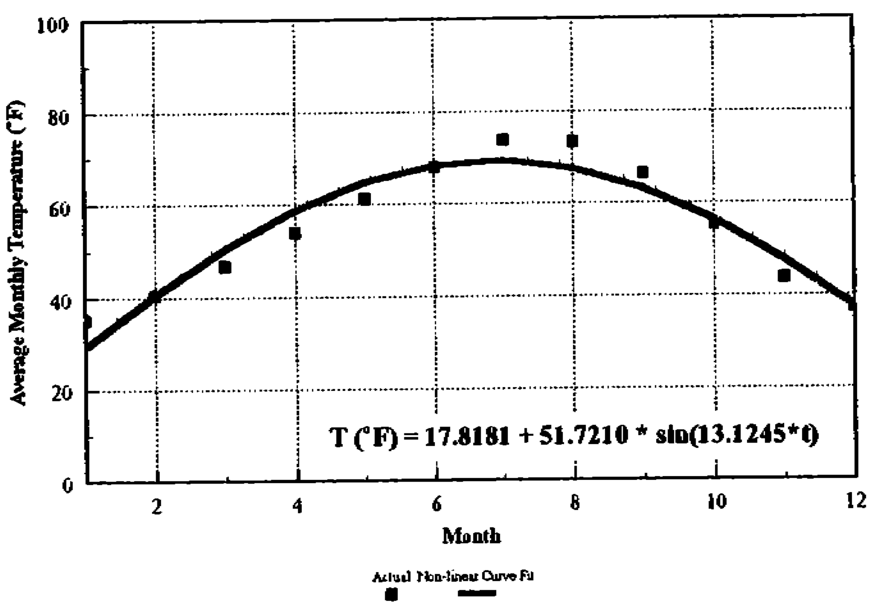
AVOCA, PA



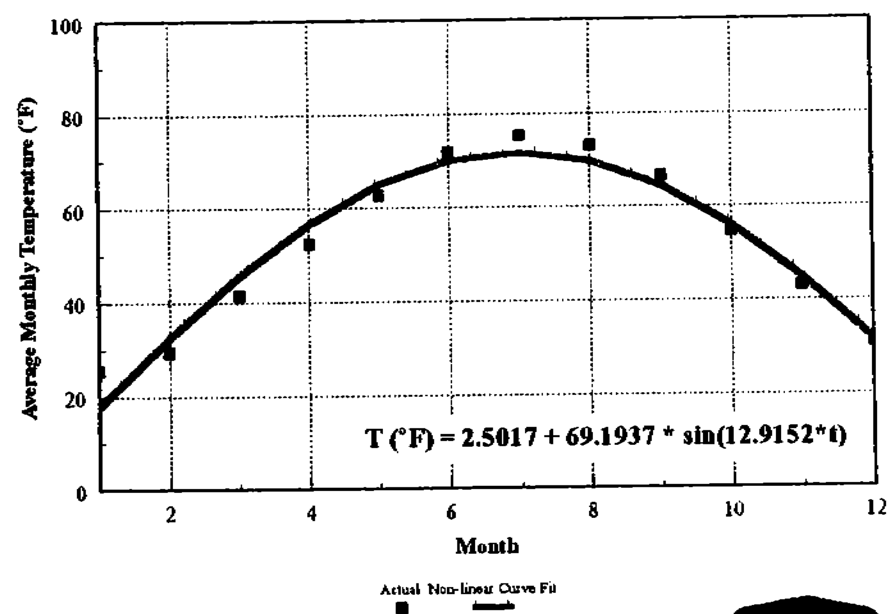
COLUMBUS, MS



THE DALLES, OR



INDIANAPOLIS, IN



AVERAGE MONTHLY TEMPERATURES FOR KMCC FACILITIES

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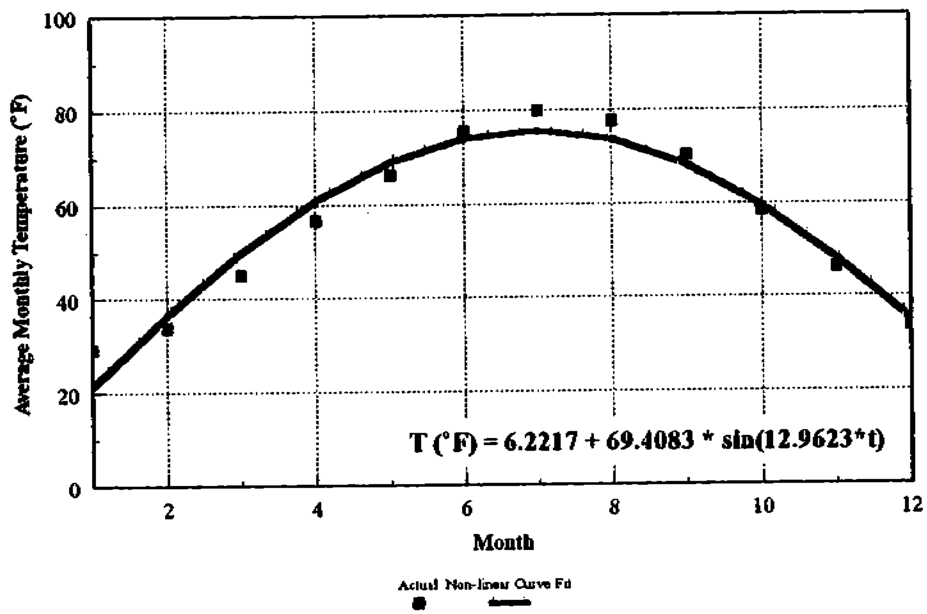
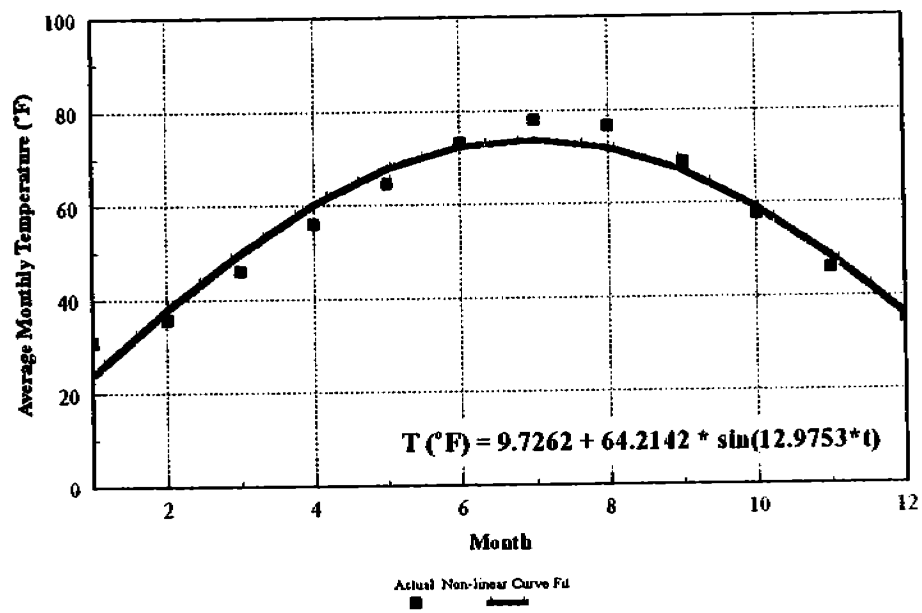
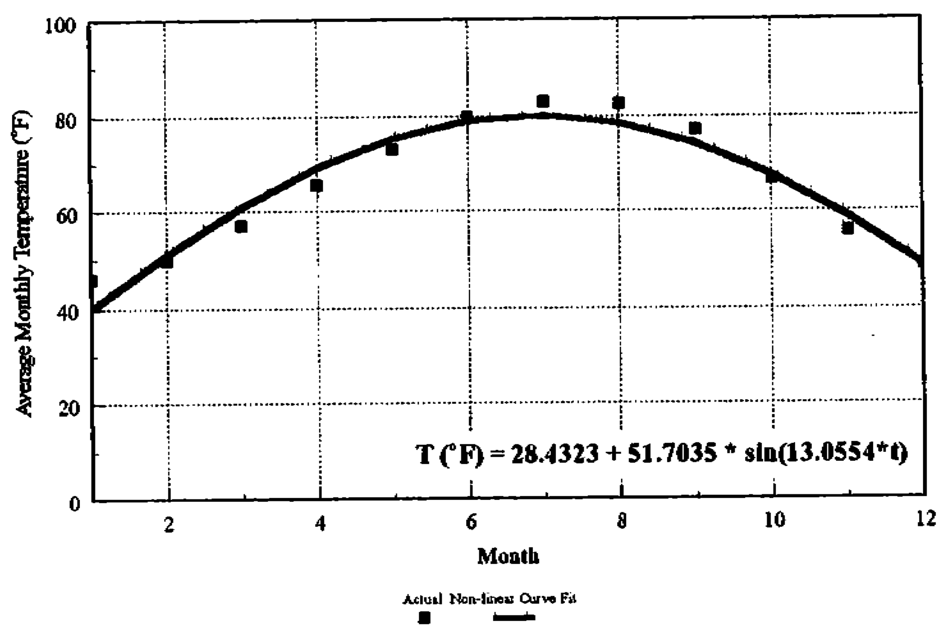
MADISON, IL



SPRINGFIELD, MO



TEXARKANA, TX



AVERAGE MONTHLY TEMPERATURES FOR KMCC FACILITIES (cont.)

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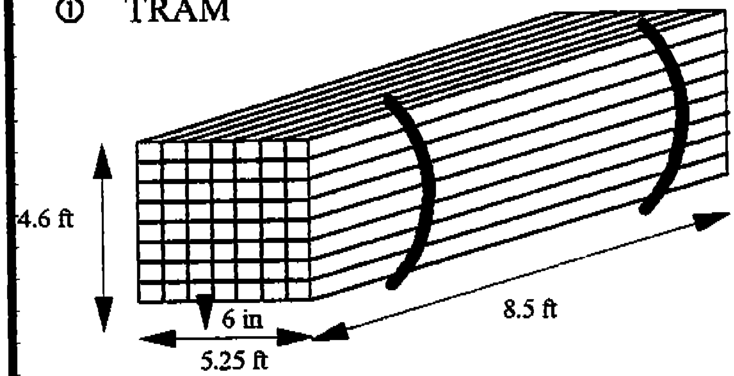
GEOMETRY OF TIE STACKS

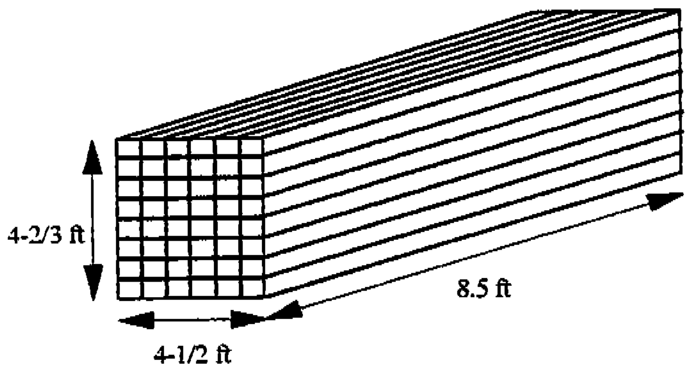
ONE TIE SURFACE AREA (7 in x 9 in x 8.5 ft) = 23.55 ft² ✓

① TRAM



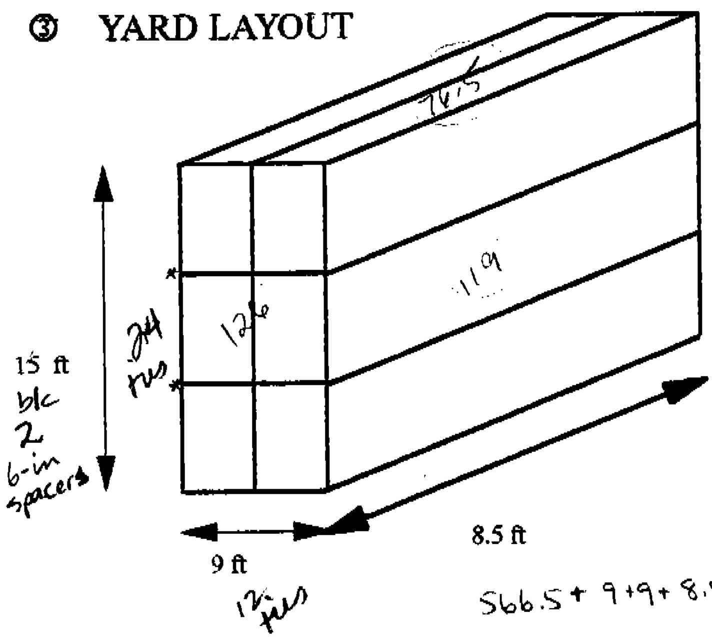
46 TIES PER TRAM
17 TRAMS PER CHARGE
TOTAL TRAM SURFACE AREA =
171 ft²

② BUNDLE



ASSUME 48 TIES = 1 BUNDLE
SURFACE AREA = 197.83 ft² ✓

③ YARD LAYOUT



288 TIES IN 6 BUNDLES = 1 STACK
SURFACE AREA = 542.5 ft² ?

SURFACE AREA OF 288 STACKED TIES =
SURFACE AREA OF INDIVIDUAL TIES

$$\frac{542.5 \text{ ft}^2}{(23.55 \text{ ft}^2)(288)} = \frac{542.5 \text{ ft}^2}{6{,}782.4} = 0.08$$

STACKING RESULTS IN 92%
REDUCTION IN SURFACE AREA
FROM SINGLE TIES

566.5 + 9+9+8.5+8.5 = 601.5 ft²

93,888 TIES PLACED IN 326 STACKS = 1 UNIT/MONTH PRODUCED
SURFACE AREA = SURFACE AREA OF ONE STACK * 326 STACKS

or

542.5 ft² * 326 STACKS = 176,855 ft²/UNIT

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ASSUMPTIONS for BLACK TIES

- TREATED TIES ARE PLACED IN STORAGE ONLY DURING DECEMBER TO MARCH, AT THE BEGINNING OF EACH MONTH
- TREATED TIES ARE SHIPPED ONLY DURING APRIL TO NOVEMBER
- ONE UNIT CONSISTS OF 652 STACKS OF 144 TIES OR 93,888 TIES
- OLDEST TIES ARE SHIPPED FIRST EACH MONTH
- ONE 652-COUNT UNIT (93,888 TIES) IS TREATED EACH MONTH
- TIES, BUNDLES, AND STACKS ARE STORED IN SUCH A WAY THAT ONLY OUTSIDE SURFACES HAVE THE POTENTIAL TO EMIT
- THE AREAL EMISSION SOURCE IS CALCULATED AS 6 - 48 CROSS TIE UNITS STACKED 3 HIGH AND 2 WIDE. THE TOTAL AREA AVAILABLE FOR EMISSIONS FROM THIS UNIT SOURCE IS 542.5 ft^2.

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ESTIMATED NAPHTHALENE EMISSIONS FROM A BLACK TIE STORAGE YARD

Facility	Kerr-McGee Chemical Corporation				
Location	Avoca, PA				
Max. Ties On Site	469,440 (Maximum Scenario - On-site Maximum is Normally 200,000 ties.)				
Min. Ties On Site	93,888				
Ties/Unit	93,888				
S.A. of Six 48-tie Bundles	601.5 ft²				
Diameter of Test Pole	11 in				
Length of Test Pole	40 ft				
No. of Test Poles	6 poles				
S.A. of Test Poles	699 ft²				
Emissions (mg/hr):	N1(t) =	18,104	* exp (	0.46683 * t),	t <= 0.25 days
(Based on 6 poles with a	N2(t) =	36,697	* exp (	-2.43497 * t),	0.25 < t <= 1.0 day
699 ft² surface area)	N3(t) =	3,347	* exp (	-0.04358 * t),	t > 1.0 day
Emissions (lb/day/ft²):	N1(t) =	1.370E-03	* exp (	0.46683 * t),	t <= 0.25 days
(Based on 6 poles with a	N2(t) =	2.777E-03	* exp (	-2.43497 * t),	0.25 < t <= 1.0 day
699 ft² surface area)	N3(t) =	2.533E-04	* exp (	-0.04358 * t),	t > 1.0 day

Calculated 24-hr Average California Pole Test Temperature = 80 °F

Temperature Correction Factor for Other Geographic Locations = exp[-11,161.25*(1/(T, °F+460)-1/(80+460))]

Assumes 30 days/month

ASSUMES 15' HIGH & NO EMISSIONS FROM BOTTOM

Month	Black Tie Units on Site	No. of Black Ties	No. of 288-Tie Stacks	Total Yard Surface Area (ft²)	Percent of Ties __ Months Old: 0 mo. 0-30 d	1 mo. 30-60 d	2 mo. 60-90 d	3 mo. 90-120 d	4 mo. 120-150 d	Tram Emissions: Surface Area (93,888 ties/mo) (ft²/month)	N1 Rate (lb/ft²) 0-0.25 d	N2 Rate (lb/ft²) 0.25-1.0 d	Yard Emissions * Percent of Ties __ Months Old, Rate N3(t) Emissions (lb naphthalene/ft² treated surface area): 1.0-30 d	30-60 d	60-90 d	90-120 d	120-150 d	Tram Sum	Yard Sum	Scranton, PA Average Temperature (°F)	Temperature Correction Factor	Total Naphthalene Emissions (lb)
1	3	281,664	978	588,267	33.3	33.3	33.3			349,529	3.63E-04	5.21E-04	1.33E-03	3.81E-04	1.03E-04			8.84E-04	1.82E-03	25.2	0.097	131
2	4	375,552	1,304	784,356	25.0	25.0	25.0	25.0		349,529	3.63E-04	5.21E-04	9.98E-04	2.87E-04	7.76E-05	2.10E-05		8.84E-04	1.38E-03	26.8	0.104	146
3	5	469,440	1,630	980,445	20.0	20.0	20.0	20.0	20.0	349,529	3.63E-04	5.21E-04	7.99E-04	2.29E-04	6.21E-05	1.68E-05	4.54E-06	8.84E-04	1.11E-03	36.1	0.161	225
4	4.43	415,790	1,444	868,394	22.6	22.6	22.6	22.6	9.7	349,529	3.63E-04	5.21E-04	9.02E-04	2.59E-04	7.01E-05	1.90E-05	2.20E-06	8.84E-04	1.25E-03	48.3	0.276	385
5	3.86	362,139	1,257	756,343	25.9	25.9	25.9	22.2		349,529	3.63E-04	5.21E-04	1.04E-03	2.97E-04	8.05E-05	1.87E-05		8.84E-04	1.43E-03	58.6	0.426	593
6	3.29	308,489	1,071	644,292	30.4	30.4	30.4	8.7		349,529	3.63E-04	5.21E-04	1.22E-03	3.49E-04	9.45E-05	7.30E-06		8.84E-04	1.67E-03	67.4	0.610	844
7	2.71	254,839	885	532,242	36.8	36.8	26.3			349,529	3.63E-04	5.21E-04	1.47E-03	4.23E-04	8.17E-05			8.84E-04	1.98E-03	71.8	0.727	989
8	2.14	201,189	699	420,191	46.7	46.7	6.7			349,529	3.63E-04	5.21E-04	1.86E-03	5.35E-04	2.07E-05			8.84E-04	2.42E-03	70.0	0.677	897
9	1.57	147,538	512	308,140	63.6	36.4				349,529	3.63E-04	5.21E-04	2.54E-03	4.17E-04				8.84E-04	2.96E-03	62.8	0.507	618
10	1	93,888	326	196,089	100.0					349,529	3.63E-04	5.21E-04	3.99E-03					8.84E-04	3.99E-03	51.7	0.319	348
11	1	93,888	326	196,089	100.0					349,529	3.63E-04	5.21E-04	3.99E-03					8.84E-04	3.99E-03	40.9	0.199	218
12	2	187,776	652	392,178	50.0	50.0				349,529	3.63E-04	5.21E-04	2.00E-03	5.74E-04				8.84E-04	2.57E-03	29.7	0.120	158

Emissions for maximum on-site storage of 469440 ties is:	Total (lb/yr)	5,553
	Total (tons/yr)	2.78
The maximum on-site Avoca storage is 200,000 ties. The emissions are:	Total (tons/yr)	1.39

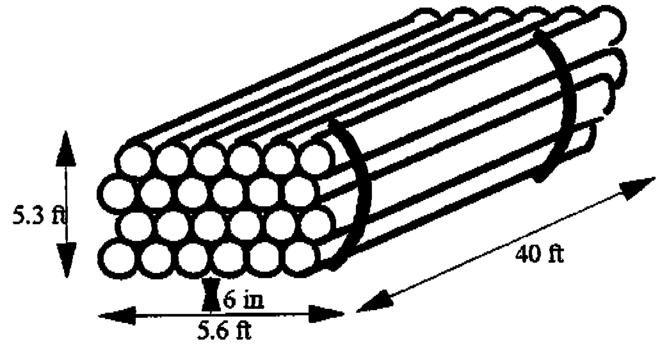
ESTIMATED NAPHTHALENE EMISSIONS FROM A BLACK TIE STORAGE YARD

Facility	Kerr-McGee Chemical Corporation			
Location	Avoca, PA			
Max. Ties On Site	234,720 (Normal Scenario - Maximum On-site Storage is about 200,000 ties.)			
Min. Ties On Site	46,944			
Ties/Unit	46,944			
S.A. of Six 48-tie Bundles	601.5 ft²			
Diameter of Test Pole	11 in			
Length of Test Pole	40 ft			
No. of Test Poles	6 poles			
S.A. of Test Poles	699 ft²			
Emissions (mg/hr):	N1(t) =	18,104	* exp (	0.46683 * t), t <= 0.25 days
(Based on 6 poles with a	N2(t) =	36,697	* exp (	-2.43497 * t), 0.25 < t <= 1.0 day
699 ft² surface area)	N3(t) =	3,347	* exp (	-0.04358 * t), t > 1.0 day
Emissions (lb/day/ft²):	N1(t) =	1.370E-03	* exp (	0.46683 * t), t <= 0.25 days
(Based on 6 poles with a	N2(t) =	2.777E-03	* exp (	-2.43497 * t), 0.25 < t <= 1.0 day
699 ft² surface area)	N3(t) =	2.533E-04	* exp (	-0.04358 * t), t > 1.0 day
Calculated 24-hr Average California Pole Test Temperature =	80 °F			
Temperature Correction Factor for Other Geographic Locations = exp[-11,161.25*(1/(T, °F+460)-1/(80+460)]				
Assumes 30 days/month				

Month	Black Tie Units on Site	No. of Black Ties	No. of 288-Tie Stacks	Total Yard Surface Area (ft²)	Percent of Ties __ Months Old: 0 mo. 0-30 d	1 mo. 30-60 d	2 mo. 60-90 d	3 mo. 90-120 d	4 mo. 120-150 d	Tram Emissions: Surface Area (46,944 ties/mo) (ft²/month)	N1 Rate (lb/ft²) 0-0.25 d	N2 Rate (lb/ft²) 0.25-1.0 d	Yard Emissions * Percent of Ties __ Months Old, Rate N3(t) Emissions (lb naphthalene/ft² treated surface area): 1.0-30 d	30-60 d	60-90 d	90-120 d	120-150 d	Tram Sum	Yard Sum	Scranton, PA Average Temperature (°F)	Temperature Correction Factor	Total Naphthalene Emissions (lb)
1	3	140,832	489	294,134	33.3	33.3	33.3			174,637	3.63E-04	5.21E-04	1.33E-03	3.82E-04	1.03E-04			8.84E-04	1.82E-03	25.2	0.097	67
2	4	187,776	652	392,178	25.0	25.0	25.0	25.0		174,637	3.63E-04	5.21E-04	9.98E-04	2.87E-04	7.76E-05	2.10E-05		8.84E-04	1.38E-03	26.8	0.104	73
3	5	234,720	815	490,223	20.0	20.0	20.0	20.0	20.0	174,637	3.63E-04	5.21E-04	7.99E-04	2.29E-04	6.21E-05	1.68E-05	4.54E-06	8.84E-04	1.11E-03	36.1	0.161	112
4	4.43	207,895	722	434,197	22.6	22.6	22.6	22.6	9.7	174,637	3.63E-04	5.21E-04	9.02E-04	2.59E-04	7.01E-05	1.90E-05	2.20E-06	8.84E-04	1.25E-03	48.3	0.276	192
5	3.86	181,070	629	378,172	25.9	25.9	25.9	22.2		174,637	3.63E-04	5.21E-04	1.04E-03	2.97E-04	8.05E-05	1.87E-05		8.84E-04	1.43E-03	58.6	0.426	297
6	3.29	154,245	536	322,146	30.4	30.4	30.4	8.7		174,637	3.63E-04	5.21E-04	1.22E-03	3.49E-04	9.45E-05	7.30E-06		8.84E-04	1.67E-03	67.4	0.610	422
7	2.71	127,419	442	266,121	36.8	36.8	26.3			174,637	3.63E-04	5.21E-04	1.47E-03	4.23E-04	8.17E-05			8.84E-04	1.98E-03	71.8	0.727	494
8	2.14	100,594	349	210,095	46.7	46.7	6.7			174,637	3.63E-04	5.21E-04	1.86E-03	5.35E-04	2.07E-05			8.84E-04	2.42E-03	70.0	0.677	449
9	1.57	73,769	256	154,070	63.6	36.4				174,637	3.63E-04	5.21E-04	2.54E-03	4.17E-04				8.84E-04	2.96E-03	62.8	0.507	309
10	1	46,944	163	98,045	100.0					174,637	3.63E-04	5.21E-04	3.99E-03					8.84E-04	3.99E-03	51.7	0.319	174
11	1	46,944	163	98,045	100.0					174,637	3.63E-04	5.21E-04	3.99E-03					8.84E-04	3.99E-03	40.9	0.199	109
12	2	93,888	326	196,089	50.0	50.0				174,637	3.63E-04	5.21E-04	2.00E-03	5.74E-04				8.84E-04	2.57E-03	29.7	0.120	79
														Emissions for maximum on-site storage of 234720 ties is:							Total (lb/yr)	2,776
																					Total (tons/yr)	1.39

GEOMETRY of POLE STACKS

① TRAM

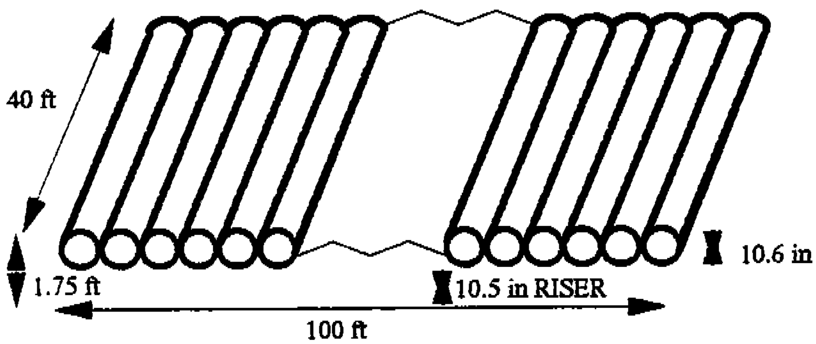


24-28 POLES per TRAM
4-5 TRAMS per CHARGE
MAX EMISSION RATES ON TRAM

TIME ON TRAM	7-8 hours
TIME IN RAILTRUCK	16 hours

TOTAL TRAM SURFACE AREA =
709 ft^2/TRAM

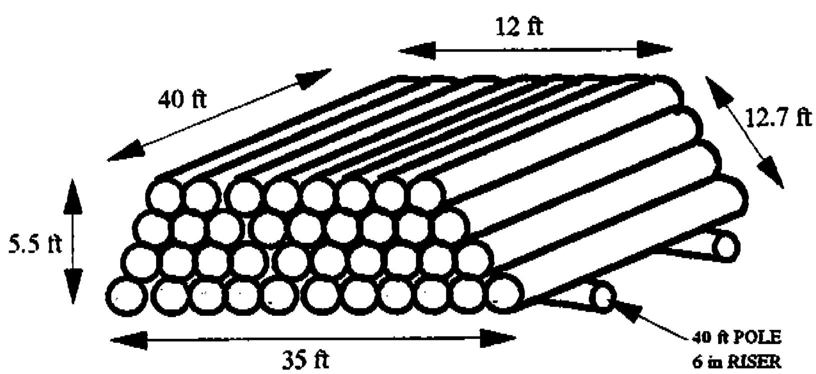
② 100 LAYOUT



100 POLES - 100% ASSAY
1 LAYOUT AREA

TIME IN LAYOUT MAX 36 hours
SHIPPED OFF-SITE
LAYOUT SURFACE AREA =
4,496 ft^2/LAYOUT

③ YARD LAYOUT



?

80 POLES PER STACK
YARD AREA = 1,806 ft^2/STACK

TIME IN YARD 3-4 months
MAXIMUM INVENTORY =
2,000 POLES

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ASSUMPTIONS for POLES

- POLE BUNDLES AND STACKS HAVE POTENTIAL TO EMIT FROM 5 SURFACES; BOTTOM EMISSIONS ARE ACCOUNTED FOR AS SIDES AND ENDS. ?

- INVENTORY OF POLES ARE RELATIVELY STABLE THROUGHOUT THE YEAR.
  TIME IN INVENTORY - 3 MONTHS.

- MAXIMUM INVENTORY OF 2,000 POLES AT ONE TIME.

- 24-28 POLES PER TRAM; 4 TRAMS PER CHARGE; 8 HRS ON TRAM.

- 100 POLES PER 100% LAYOUT; 36 HOURS FOR LAYOUT; ALL POLES GET 100% LAYOUT
  5 SURFACE AREAS - 100 ft x 1.75 ft x 40 ft.

- MAXIMUM 80 POLES PER STACK:
  STACK HAS TRAPEZOID SHAPE - 12 ft (TOP) x 35 ft (BOTTOM) x 5.5 ft (HEIGHT)
  5 SURFACE AREAS -
  STACK RISER EQUIVALENT TO 0.5 ft.

- ALL HEIGHTS ARE FROM GROUND LEVEL FOR DETERMINING SURFACE AREA.

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ESTIMATED NAPHTHALENE EMISSIONS FROM A BLACK POLE (CREOSOTE) STORAGE YARD

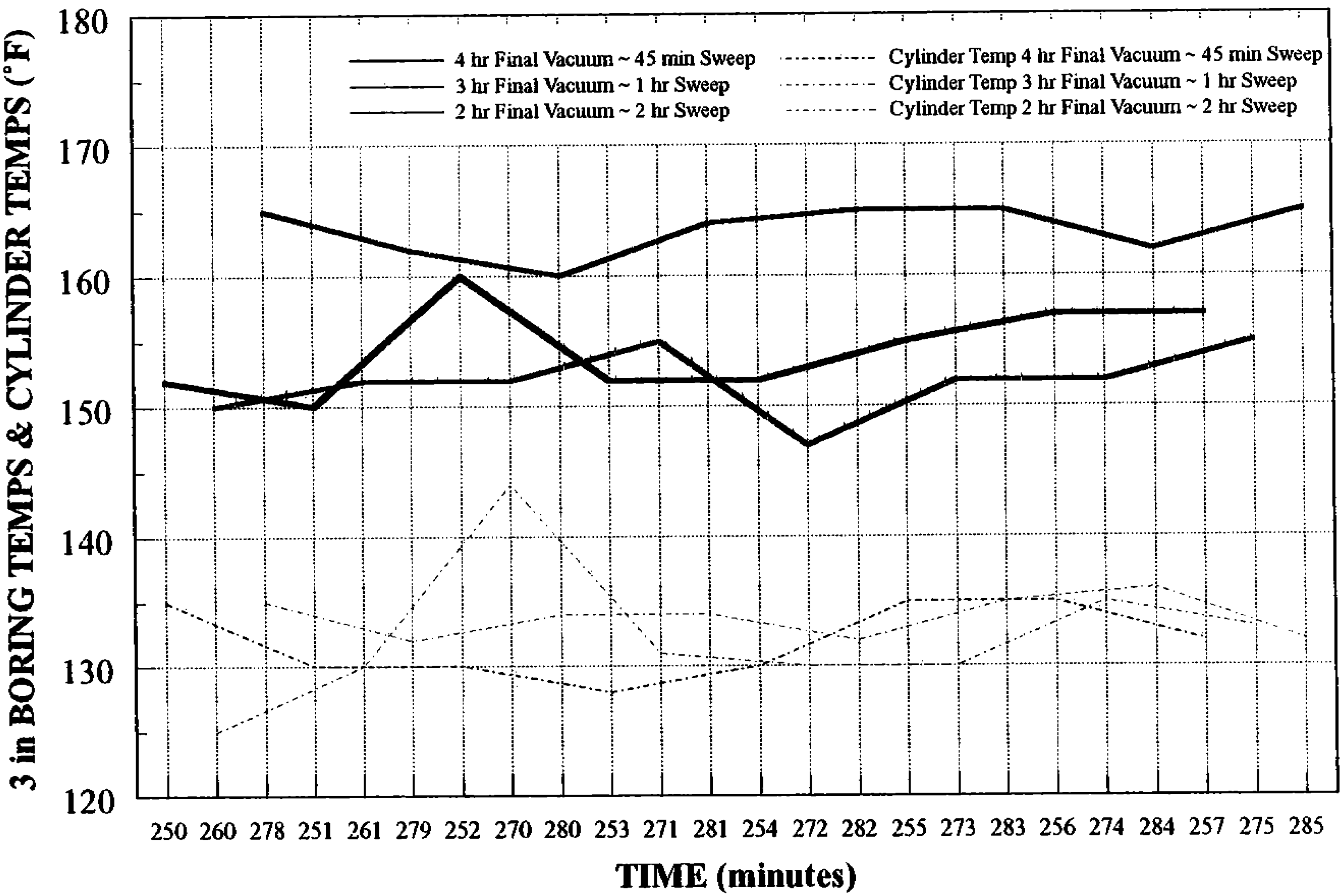
Facility	Koppers				
Location	Grenada, MS				
Max. Poles On Site	2,600				
Min. Poles On Site	2,600				
Poles Unit	2,600				
S.A. of 80-Pole Stack	1,806 ft² (modeled as planar surfaces, excludes bottom)				
Diameter of Test Pole	11 in				
Length of Test Pole	40 ft				
No. of Test Poles	6 poles				
S.A. of Test Poles	699 ft²				
Emissions (mg/hr):	N1(t) =	18,104	* exp (	0.46683 * t),	t <= 0.25 days
(Based on 6 poles with a	N2(t) =	36,693	* exp (	-2.43493 * t),	0.25 < t <= 1.0 day
699 ft² surface area)	N3(t) =	3,143	* exp (	-0.04358 * t),	t > 1.0 day
Emissions (lb/day/ft²):	N1(t) =	1.370E-03	* exp (	0.46683 * t),	t <= 0.25 days
(Based on 6 poles with a	N2(t) =	2.777E-03	* exp (	-2.43497 * t),	0.25 < t <= 1.0 day
699 ft² surface area)	N3(t) =	2.331E-04	* exp (	-0.04358 * t),	t > 1.0 day
Calculated 24-hr Average California Pole Test Temperature =	80 °F				
Temperature Correction Factor for Other Geographic Locations = exp[-16,161.25*(1/(T, °F+460)-1/(80+460))]					
Assumes 30 days/month					

Month	Black Pole Units on Site	No. of Black Poles	No. of 80-Pole Stacks	Total Surface Area (ft²)	Percent of Poles __ Months Old: 0 mo. (0-30 d)	1 mo. (30-60 d)	2 mo. (60-90 d)	3 mo. (90-120 d)	4 mo. (120-150 d)	Tram Layout: Surface Area (2,600 poles/mo) (ft²/month)	N1 Rate (lb/ft²) 0-0.25 d	100 Pole Layout: Surface Area (2,600 poles/mo) (ft²/month)	N2 Rate (lb/ft²) 0.25-1.0 d	N3 Rate (lb/ft²) 1.0-1.5 d
1	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
2	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
3	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
4	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
5	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
6	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
7	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
8	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
9	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
10	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
11	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04
12	1.0	2,600	33	58,695	33.3	33.3	33.3			76,808	3.63E-04	116,896	5.21E-04	1.20E-04

Month	Yard Emissions * Percent of Poles __ Months Old, Rate N3(t) Emissions (lb naphthalene/ft² treated wood): 1.5-30 d	30-60 d	60-90 d	90-120 d	120-150 d	Tram Sum	100 Layout Sum	Yard Sum	Columbus, MS Average Temperature (°F)	Temperature Correction Factor	Total Naphthalene Emissions (lb)
1	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	41.2	0.202	42
2	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	44.9	0.238	49
3	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	52.6	0.331	69
4	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	62.6	0.502	104
5	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	70.4	0.688	142
6	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	77.3	0.915	190
7	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	80.9	1.035	214
8	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	80.1	1.004	208
9	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	74.1	0.796	165
10	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	62.3	0.496	103
11	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	51.1	0.311	64
12	1.29E-03	3.82E-04	1.03E-04	--	--	3.63E-04	6.41E-04	1.78E-03	44.4	0.229	48
	Emissions for maximum on-site storage of 2600 poles is:									Total (lb/yr)	1,397
										Total (ton/yr)	0.70

VACUUM and SWEEP STATISTICS

3 in TIE & CYLINDER TEMPERATURES OVER TIME



SUMMARY and CONCLUSIONS

- EMISSIONS ARE DEPENDENT UPON VAPOR PRESSURE
  - VAPOR PRESSURE IS DRIVEN BY TEMPERATURE
- EMISSION RATES FOLLOW FIRST ORDER KINETICS
- THREE PHASES OCCUR IN EMISSION RATES:
  - 1ST 0 - 12 HOURS INCREASE/DECREASE HIGH
  - 2ND 12 - 24 HOURS DECREASES LOW
  - 3RD + 24 HOURS STABILIZES
- EMISSION RATES DEPENDENT UPON EXPOSED SURFACE AREAS
- MAXIMUM INVENTORY OF TIES OCCURS IN WINTER
- POLE INVENTORIES ARE CONSISTENT THROUGHOUT THE YEAR
- LONG TERM EMISSION RATES ARE DEPENDENT UPON AMBIENT TEMPERATURE
- ANNUAL STORAGE EMISSIONS FOR CREOSOTE TIES AT AVOCA, PENNSYLVANIA WERE 1.39 TPY
- ANNUAL EMISSIONS FOR CREOSOTE POLES AT GRENADA, MISSISSIPPI WERE 0.70 TPY

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CALCULATED NAPHTHALENE EMISSIONS FROM BLACK TIE STORAGE YARDS

These calculations were designed to calculate the naphthalene emissions from creosote-treated railroad ties in a storage yard. Naphthalene emissions from black ties were based on emissions monitoring data from creosote-treated telephone poles at the Koppers plant in Oroville, CA (the Feather River plant). The first step was to determine a relationship between the emissions and time. Three curves were fit to the available data, because it was found that one curve would not adequately represent all of the data. It was determined that the emissions data represented three distinct phenomena: 1) temperature-driven emissions: the emissions of newly-treated ties and poles increased briefly after removal from the retort (0 to 6 hr), 2) thin-film evaporative emissions: emission rates then decreased rapidly (6 to 24 hr), and 3) ambient-temperature emissions: emissions stabilized at a lower level once the initial film dissipated (24+ hr). The emission equations representing these three rates are shown in Equation (1). The second equation of each set is on an area basis, derived from the 699 ft^2 surface area of the six creosote-treated poles on which the original emission test was done.

Temperature-Driven Emissions (Rate 1):

$$N_1(t)\left(\frac{mg\ naphthalene}{hr}\right) = 18,104\,e^{(0.46683*t)},\quad t \le 0.25\ days$$

$$N_1(t)\left(\frac{lb\ naphthalene}{ft^2\text{-}day}\right) = 1.370*10^{-3}\,e^{(0.46683*t)},\quad t \le 0.25\ days$$

Thin-Film Emissions (Rate 2):

$$N_2(t)\left(\frac{mg\ naphthalene}{hr}\right) = 36,697\,e^{(-2.43497*t)},\ 0.25 < t \le 1.0\ day \qquad (1)$$

$$N_2(t)\left(\frac{lb\ naphthalene}{ft^2\text{-}day}\right) = 2.777*10^{-3}\,e^{(-2.43497*t)},\quad 0.25 < t \le 1.0\ day$$

Pore-Space Emissions (Rate 3):

$$N_3(t)\left(\frac{mg\ naphthalene}{hr}\right) = 3,347\,e^{(-0.04358*t)},\ t > 1.0\ day$$

$$N_3(t)\left(\frac{lb\ naphthalene}{ft^2\text{-}day}\right) = 2.533*10^{-4}\,e^{(-0.04358*t)},\ t > 1.0\ day$$

An age distribution was constructed which determined the percentage of stored black ties at a given age during any month. The percentage age distribution can apply to any KMCC site, because each facility follows the same general treating and shipping schedule. It was assumed that:

- The same number of ties was treated every month,
- When shipping occurred, the oldest treated wood was shipped off-site,
- When shipping occurred, the same number of ties were shipped off-site,
- No ties were shipped between December and March (building inventory), and
- Ties were shipped off-site during the months of April through November only.

Using January as an example, one-third of the treated wood would be newly-treated (0 months old), one-third would be 1 month old, and one-third would be 2 months old. During February, one-quarter of treated wood would be newly-treated, one-quarter would be 1 month old, one-quarter would be 2 months old, and one-quarter would be 3 months old. This age distribution showed that no stored ties were ever more than 4 months old. The distribution is also conservative in that aged black ties (with fewer emissions) were shipped out first each month, keeping the higher-emitting newly-treated wood ties on-site. The age distribution is shown below.

AGE DISTRIBUTION EXPRESSED AS A PERCENTAGE OF STORED BLACK TIES

Month	Percent of Ties __ Months Old:				
	0 Month	1 Month	2 Months	3 Months	4 Months
1	33	33	33		
2	25	25	25	25	
3	20	20	20	20	20
4	22.6	22.6	22.6	22.6	9.7
5	26	26	26	22	
6	30.4	30.4	30.4	8.7	
7	37	37	26		
8	47	47	6.7		
9	64	36			
10	100				
11	100				
12	50	50			

26

The stacking geometry assumed six bundles of 48 ~~poles~~ ties each, stacked 2 bundles wide and 3 bundles high. Between the bundles stacked 3 high are 6 inch spacers. The 6 inch spaces between the stacked bundles were assumed to contain air saturated with naphthalene, those spaces were treated as if they contained treated ties. Each of the stacks therefore contained 288 treated ties, with an external surface area of 601.5 ft^2.

Black tie emissions were calculated from the time the treated wood was removed from the retort. All treated ties were assumed to remain on trams for 24 hours before being moved to the storage yard and restacked in the 288-pole geometry described above. The age distribution was not applied to black ties on trams, because it only applies to the storage yard.

For emissions calculation purposes, each month was assumed to have 30 days. Using January as an example, the following conditions applied:

- Black Ties On Site: 281,664 ties
- Black Ties Produced: 93,888 ties
- Surface Area of Black Ties on Trams: 349,529 ft^2
- Number of 288-Tie Bundles: 978 bundles
- Surface Area of Each 288-Tie Bundle: 601.5 ft^2
- Total Surface Area of Yard Stacks: 588,267 ft^2
- Percent of Black Ties On-site in January which are:

0 Months Old	33.3 %
1 Month Old	33.3 %
2 Months Old	33.3 %

The total emission loading for any time period is simply the area under the appropriate rate curve for that time period. Therefore, integration between times t_1 and t_2 (days) was performed as shown in Equation 2. The emission expressions are of the form Ae^{-kt}, as was demonstrated in Equation (1).

$$\int_{t_1}^{t_2} Ae^{-kt}\,dt = A\int_{t_1}^{t_2} e^{-kt}\,dt = -\left(\frac{A}{k}\right)\left[e^{-kt}\right]_{t_1}^{t_2} = -\left(\frac{A}{k}\right)\left(e^{-kt_2}-e^{-kt_1}\right), \qquad (2)$$

where A and k are constants.

Black ties were assumed to be stored on the trams for 24 hours (1 day), which is a very conservative estimate. The emissions must therefore be divided into Rate 1 Emissions (0 to 0.25 days) and Rate 2 emissions (0.25 to 1.0 days). Rate 1 emissions for January for treated ties on trams for less than 0.25 days were integrated between the limits of t = 0 to 0.25 days. The result is shown in Equation (3).

$$\int_{0}^{0.25} 1.370 * 10^{-3} e^{0.46683t}\, dt = \left(\frac{1.370 * 10^{-3}}{0.46683}\right)\left(e^{(0.46683*0.25)} - e^{(0.46683*0)}\right) \tag{3}$$

$$= 0.000363 \frac{lb\ naphthalene}{ft^2\ of\ treated\ surface\ area}$$

Rate 2 emissions from black ties on trams for 0.25 to 1.0 days were calculated as shown in Equation (4).

$$\int_{0.25}^{1.0} 2.777 * 10^{-3} e^{-2.43497t}\, dt = -\left(\frac{2.777 * 10^{-3}}{2.43497}\right)\left(e^{(-2.43497*1.0)} - e^{(-2.43497*0.25)}\right) \tag{4}$$

$$= 0.000521 \frac{lb\ naphthalene}{ft^2\ of\ treated\ surface\ area}$$

After 1 day on the trams, ties were moved to the storage yard. Rate 3 emissions for black ties which are between 1 and 30 days old and on-site during January are calculated in Equation (5). The age distribution factor of 33.3% is also applied in the equation.

$$\int_{1}^{30} 2.533 * 10^{-4} e^{-0.04358t}\, dt = -\left(\frac{2.533 * 10^{-3}}{-0.04358}\right)\left(e^{(-0.04358*30)} - e^{(-0.04358*1)}\right) * (0.333) \tag{5}$$

← TYPO - denom. should not be [illegible] numerator changed [illegible]

✓ $$= 0.00133 \frac{lb\ naphthalene}{ft^2\ of\ treated\ surface\ area}$$

Emissions for month 2 (60 to 90 days), month 3 (90 to 120 days), and month 4 (120 to 150 days) were calculated by changing the time limits in Equation (5). The total emissions for January are equal to the sum of the integrated emissions from 0 to 90 days, because the age distribution showed no ties older than 2 months (0 to 90 days). Note that all January yard emissions have the same age distribution factor of 33.3%.

A summation of the January emissions is shown in Equation (6).

Rate 1 $EF_1 = 0.00293\left(e^{0.46683t} - 1\right)$

Rate 2 $EF_2 = -0.00114\left(e^{-2.43497t_2} - e^{-2.43497t_1}\right)$

Rate 3 $EF_3 =$ ~~-0.0581~~ $\left(e^{-0.04358t_2} - e^{-0.04358t_3}\right)$

↑ +0.00581

Correct eqn.

$EF_3 = 0.00581\left(e^{-0.04358} - e^{-0.04358t_3}\right)$

January Emissions:

From Trams:

A $0 \text{ to } 0.25 \text{ days} = 0.000363 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right)$

B $0.25 \text{ to } 1.0 \text{ day} = 0.000521 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right)$

A + B = $\sum_{t=0}^{t=1} = 0.000884 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right)$

$0.000884 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right) * 349{,}529\ (ft^2\ treated\ area)$

$= 309\ (lb\ naphthalene)$

From Storage Yard: (6)

C $1.0 \text{ to } 30 \text{ days} = 0.003993 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right)$

D $30 \text{ to } 60 \text{ days} = 0.001147 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right)$

E $60 \text{ to } 90 \text{ days} = 0.000310 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right)$

C + D + E = $\sum_{t=1}^{90\ days} N_i(t) = 0.00545 \left(\frac{lb\ naphthalene}{ft^2\ treated\ area}\right)$

$* 588{,}267\ ft^2$ *treated area* * 0.333 (*age distribution*)

= 1,067.6 *lb naphthalene emitted during January from Yard*

January Total Emissions = 309 + 1,067.7 = 1,376.6 *lb naphthalene*

29

The vapor pressure of naphthalene increases exponentially as the temperature increases, and therefore naphthalene emissions from black ties are expected to do the same. It follows that the temperature correction factor should also be represented by an exponential expression. A temperature correction factor was needed to adjust the emissions as the ambient temperature of the storage yard location varied from the 24-hour average test temperature of 80 °F in California. Intuition, and the naphthalene vapor pressure data, indicated that emission rates should rise as the temperature rises, and fall as the temperature falls. The temperature correction factor was defined as the ratio of naphthalene's vapor pressure at the average monthly temperature of the wood treating site to the vapor pressure evaluated at the average test temperature of 80 °F. Equation 7 shows the derivation of the temperature correction factor equation, and its calculation for Kerr-McGee's Avoca, PA site.

$$\textit{Naphthalene Vapor Pressure (mm Hg)} = 2.616 * 10^{8} e^{\left(\frac{-11,161.25}{T°F + 460}\right)} = A e^{\left(\frac{B}{T}\right)}$$

Antoine's VP eqn.

$$\frac{VP(T_{avg})}{VP(T_{test})} = \frac{A e^{\left(\frac{B}{T_{avg}}\right)}}{A e^{\left(\frac{B}{T_{test}}\right)}} = \frac{e^{\left(\frac{B}{T_{avg}}\right)}}{e^{\left(\frac{B}{T_{test}}\right)}} = e^{B\left(\frac{1}{T_{avg}} - \frac{1}{T_{test}}\right)} = e^{B\left(\frac{1}{(T_{avg}°F+460)} - \frac{1}{(80°F+460)}\right)}$$

$$\textit{Temperature Correction Factor} = e^{-11,161.25\left(\frac{1}{(T_{avg}°F+460)} - \frac{1}{(80°F+460)}\right)} \qquad (7)$$

For January, T_{avg} = 25.2 °*F, which is less than the original test temperature of* 80 °*F, so the temperature correction factor will be less than one:*

$$\textit{Temperature Correction Factor} = e^{-11,161.25\left(\frac{1}{(25.2°F+460)} - \frac{1}{(80°F+460)}\right)} = 0.097$$

Note that a temperature correction factor of 1 *results if* T_{avg}=80°*F.*

The total monthly emissions for January were calculated as the product of the monthly emissions in lb naphthalene/ft^2, the surface area of treated wood on-site during January, and the age distribution factors for treated wood in January, as shown previously. Application of the temperature correction factor is shown mathematically in Equation (8). This essentially translates the test emissions from the test site with a temperature of 80 °F (California) to a site with a colder temperature of 25.2 °F (Pennsylvania). The naphthalene vapor pressure is lower at Pennsylvania, and therefore, the emissions will be lower due to the decreased temperature.

Temperature-Corrected Emissions for January: (8)

1,376.6 (*lb naphthalene*) * (0.097) = 133 *lb naphthalene*

The procedure shown in Equations (1) through (8) was followed to determine a naphthalene emission rate for the other months in the year. The monthly rates were added to determine the annual naphthalene emissions. The calculated annual naphthalene emissions from the Avoca, PA facility's black tie storage yard was 2.78 tons/yr, assuming a maximum on-site quantity of black ties of about 470,000 ties. However, the Avoca facility generally has a yearly on-site maximum of about 234,000 black ties, which equates to 1.39 tons/year.

CALCULATED NAPHTHALENE EMISSIONS FROM BLACK POLE STORAGE YARDS

These calculations were designed to calculate the naphthalene emissions from creosote-treated telephone poles in a storage yard. Naphthalene emissions from black poles were based on emissions monitoring data from creosote-treated telephone poles at the Koppers plant in Oroville, CA (the Feather River plant). The first step was to determine a relationship between the emissions and time. Three curves were fit to the available data, because it was found that one curve would not adequately represent all of the data. It was determined that the emissions data represented three distinct phenomena: 1) temperature-driven emissions: the emissions of newly-treated poles and poles increased briefly after removal from the retort (0 to 6 hr), 2) thin-film evaporative emissions: emission rates then decreased rapidly (6 to 24 hr), and 3) ambient-temperature emissions: emissions stabilized at a lower level once the initial film dissipated (24+ hr). The emission equations representing these three rates are shown in Equation (1). The second equation of each set is on an area basis, derived from the 699 ft^2 surface area of the six creosote-treated poles on which the original emission test was done.

Temperature-Driven Emissions (Rate 1):

$$N_1(t)\left(\frac{mg\ naphthalene}{hr}\right) = 18{,}104\,e^{(0.46683*t)},\quad t \le 0.25\ days$$

$$N_1(t)\left(\frac{lb\ naphthalene}{ft^2\text{-}day}\right) = 1.370*10^{-3}\,e^{(0.46683*t)},\quad t \le 0.25\ days$$

Thin-Film Emissions (Rate 2):

$$N_2(t)\left(\frac{mg\ naphthalene}{hr}\right) = 36{,}697\,e^{(-2.43497*t)},\quad 0.25 < t \le 1.0\ day \qquad (1)$$

$$N_2(t)\left(\frac{lb\ naphthalene}{ft^2\text{-}day}\right) = 2.777*10^{-3}\,e^{(-2.43497*t)},\quad 0.25 < t \le 1.0\ day$$

Pore-Space Emissions (Rate 3):

$$N_3(t)\left(\frac{mg\ naphthalene}{hr}\right) = 3{,}347\,e^{(-0.04358*t)},\quad t > 1.0\ day$$

$$N_3(t)\left(\frac{lb\ naphthalene}{ft^2\text{-}day}\right) = 2.533*10^{-4}\,e^{(-0.04358*t)},\quad t > 1.0\ day$$

An age distribution was constructed which determined the percentage of stored black poles at a given age during any month. It was assumed that:

- The same number of poles was treated every month,
- When shipping occurred, the oldest treated wood was shipped off-site,
- When shipping occurred, the same number of poles were shipped off-site, and
- Poles were shipped off-site each month.

Using January as an example, one-third of the treated wood would be newly-treated (0 months old), one-third would be 1 month old, and one-third would be 2 months old. This age distribution applies to all months, because poles are treated and shipped year-round. This age distribution showed that no stored poles were ever more than 4 months old. The distribution is also conservative in that aged black poles (with fewer emissions) were shipped out first each month, keeping the higher-emitting newly-treated wood poles on-site. The age distribution is shown below.

AGE DISTRIBUTION EXPRESSED AS A PERCENTAGE OF STORED BLACK POLES

Month	Percent of Poles __ Months Old:				
	0 Month	1 Month	2 Months	3 Months	4 Months
1	33.3	33.3	33.3		
2	33.3	33.3	33.3		
3	33.3	33.3	33.3		
4	33.3	33.3	33.3		
5	33.3	33.3	33.3		
6	33.3	33.3	33.3		
7	33.3	33.3	33.3		
8	33.3	33.3	33.3		
9	33.3	33.3	33.3		
10	33.3	33.3	33.3		
11	33.3	33.3	33.3		
12	33.3	33.3	33.3		

33

The stacking geometry assumed a trapezoidal stack of 80 poles, each supported by a pole riser. The space between the stack and the ground was assumed to be saturated with naphthalene and counted as part of the surface area. Each of the stacks therefore contained 80 treated poles, with an external surface area of 1,806 ft^2.

Black pole emissions were calculated from the time the treated wood was removed from the retort. All treated poles were assumed to remain on trams for 6 hours before being moved to a 100 percent layout configuration, and then to the storage yard. The age distribution was not applied to black poles on trams or in the 100 percent layout configuration, as it only applies to the storage yard.

For emissions calculation purposes, each month was assumed to have 30 days. Using January as an example, the following conditions applied:

♦ Black Poles On Site:		2,600 poles
♦ Black Poles Produced:		2,600 poles
♦ Surface Area of Black Poles on Trams:		76,808 ft^2
♦ Number of 80-Pole Stacks:		33 stacks
♦ Surface Area of Each 80-Pole Stack:		1,806 ft^2
♦ Total Surface Area of Yard Stacks:		58,695 ft^2
♦ Percent of Black Poles On-site in January which are:		
	0 Months Old	33.3 %
	1 Month Old	33.3 %
	2 Months Old	33.3 %

The total emission loading for any time period is simply the area under the appropriate rate curve for that time period. Therefore, integration between times t_1 and t_2 (days) was performed as shown in Equation (2). The emission expressions are of the form Ae^{-kt}, as was demonstrated in Equation (1).

$$\int_{t_1}^{t_2} Ae^{-kt}\,dt = A\int_{t_1}^{t_2} e^{-kt}\,dt = -\left(\frac{A}{k}\right)\left[e^{-kt}\right]_{t_1}^{t_2} = -\left(\frac{A}{k}\right)\left(e^{-kt_2}-e^{-kt_1}\right), \qquad (2)$$

where A and k are constants.

Black poles were assumed to be stored on the trams for 6 hours (0.25 day). The emissions are therefore Rate 1 Emissions (0 to 0.25 days). Rate 1 emissions for January for treated poles on trams for less than 0.25 days were integrated between the limits of t = 0 to 0.25 days. The result is shown in Equation (3).

$$\int_{0}^{0.25} 1.370 * 10^{-3} e^{0.46683t}\, dt = \left(\frac{1.370 * 10^{-3}}{0.46683}\right)\left(e^{(0.46683*0.25)} - e^{(0.46683*0)}\right) \tag{3}$$

$$= 0.000363 \; \frac{\textit{lb naphthalene}}{\textit{ft}^2 \textit{ of treated surface area}}$$

All treated poles were assumed to go to a 100 percent layout configuration for 30 hours after being unloaded from the trams. Rate 2 emissions from black poles on trams for 0.25 to 1.0 day were calculated as shown in Equation (4).

$$\int_{0.25}^{1.0} 2.777 * 10^{-3} e^{-2.43497t}\, dt = -\left(\frac{2.777 * 10^{-3}}{2.43497}\right)\left(e^{(-2.43497*1.0)} - e^{(-2.43497*0.25)}\right) \tag{4}$$

$$= 0.000521 \; \frac{\textit{lb naphthalene}}{\textit{ft}^2 \textit{ of treated surface area}}$$

Rate 3 emissions for 1.0 to 1.5 days during the layout period are shown in Equation (5).

$$\int_{1}^{1.5} 2.533 * 10^{-4} e^{-0.04358t}\, dt = -\left(\frac{2.533 * 10^{-4}}{0.04358}\right)\left(e^{(-0.04538*1.5)} - e^{(-0.04358*1.0)}\right) \tag{5}$$

$$= 0.000120 \; \frac{\textit{lb naphthalene}}{\textit{ft}^2 \textit{ of treated surface area}}$$

After 1.5 days, the poles were moved to the storage yard. Rate 3 emissions for black poles which are between 1.5 and 30 days old and on-site during January are calculated in Equation (6). The age distribution factor of 33.3% is also applied in the equation.

$$\int_{1.5}^{30} 2.533 * 10^{-4} e^{-0.04358t}\, dt = -\left(\frac{2.533 * 10^{-4}}{0.04358}\right)\left(e^{(-0.04358*30)} - e^{(-0.04358*1.5)}\right) * (0.333) \tag{6}$$

$$= 0.00129 \; \frac{\textit{lb naphthalene}}{\textit{ft}^2 \textit{ of treated surface area}}$$

Emissions for month 2 (60 to 90 days), month 3 (90 to 120 days), and month 4 (120 to 150 days) were calculated by changing the time limits in Equation (6). The total emissions for January are equal to the sum of the integrated emissions from 0 to 90 days, because the age distribution showed no poles older than 2 months (0 to 90 days). Note that all January yard emissions have the same age distribution factor of 33.3%. A summary of January emissions is given in Equation (7).

January Emissions:

From Trams:

$$0 \ to \ 0.25 \ days = 0.000363 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right)$$

From Layout:

$$0.25 \ to \ 1.0 \ days = 0.000521 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right)$$

$$1.0 \ to \ 1.5 \ day = 0.000120 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right)$$

$$Trams + Layout = 0.000363 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right) * 76,808 \ (ft^2 \ treated \ area)$$

$$+ 0.000641 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right) * 116,896 \ (ft^2 \ treated \ area)$$

$$= 102.8 \ (lb \ naphthalene) \qquad (7)$$

From Storage Yard:

$$1.5 \ to \ 30 \ days = 0.00387 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right)$$

$$30 \ to \ 60 \ days = 0.001147 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right)$$

$$60 \ to \ 90 \ days = 0.000310 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right)$$

$$\sum_{t=1.5}^{90 \ days} N_1(t) = 0.00533 \left(\frac{lb \ naphthalene}{ft^2 \ treated \ area}\right)$$

$$* \ 58,695 \ ft^2 \ treated \ area * 0.333 \ (age \ distribution)$$

$$= 104.2 \ lb \ naphthalene \ emitted \ during \ January \ from \ Yard$$

$$January \ Total \ Emissions = 102.8 + 104.2 = 207 \ lb \ naphthalene$$

The vapor pressure of naphthalene increases exponentially as the temperature increases, and therefore naphthalene emissions from black poles are expected to do the same. It follows that the temperature correction factor should also be represented by an exponential expression. A temperature correction factor was needed to adjust the emissions as the ambient temperature of the storage yard location varied from the 24-hour average test temperature of 80 °F in California. Intuition, and the naphthalene vapor pressure data, indicated that emission rates should rise as the temperature rises, and fall as the temperature falls. The temperature correction factor was defined as the ratio of naphthalene's vapor pressure at the average monthly temperature of the wood treating site to the vapor pressure evaluated at the average test temperature of 80 °F. Equation (8) shows the derivation of the temperature correction factor equation, and its calculation for Koppers Grenada, MS site.

Naphthalene Vapor Pressure (mm Hg) $= 2.616 * 10^8 e^{\left(\frac{-11,161.25}{T^{\circ}F + 460}\right)} = A e^{\left(\frac{B}{T}\right)}$

$$\frac{VP(T_{avg})}{VP(T_{test})} = \frac{A e^{\left(\frac{B}{T_{avg}}\right)}}{A e^{\left(\frac{B}{T_{test}}\right)}} = \frac{e^{\left(\frac{B}{T_{avg}}\right)}}{e^{\left(\frac{B}{T_{test}}\right)}} = e^{B\left(\frac{1}{T_{avg}} - \frac{1}{T_{test}}\right)} = e^{B\left(\frac{1}{(T_{avg}{}^{\circ}F+460)} - \frac{1}{(80^{\circ}F+460)}\right)}$$

$$\text{Temperature Correction Factor} = e^{-11,161.25\left(\frac{1}{(T_{avg}{}^{\circ}F+460)} - \frac{1}{(80^{\circ}F+460)}\right)} \tag{8}$$

For January, $T_{avg} = 41.2\ ^{\circ}F$, *which is less than the original test temperature of* $80\ ^{\circ}F$, *so the temperature correction factor will be less than one:*

$$\text{Temperature Correction Factor} = e^{-11,161.25\left(\frac{1}{(41.2^{\circ}F+460)} - \frac{1}{(80^{\circ}F+460)}\right)} = 0.202$$

Note that a temperature correction factor of 1 *results if* $T_{avg} = 80^{\circ}F$.

The total monthly emissions for January were calculated as the product of the monthly emissions in lb naphthalene/ft^2, the surface area of treated wood on-site during January, and the age distribution factors for treated wood in January, as shown previously. Application of the temperature correction factor is shown mathematically in Equation (9). This essentially translates the test emissions from the test site with a temperature of 80 °F (California) to a site with a colder temperature of 41.2 °F (Mississippi). The naphthalene vapor pressure is lower in Mississippi, and therefore the emissions will be lower due to the decreased temperature.

Temperature-Corrected Emissions for January: (9)

207 (*lb naphthalene*) $*$ (0.202) = 41.8 *lb naphthalene*

The procedure shown in Equations (1) through (9) was followed to determine a naphthalene emission rate for the other months in the year. The monthly rates were added to determine the annual naphthalene emissions. The calculated annual naphthalene emissions from the Grenada, MS facility's black pole storage yard was 0.70 tons/yr.

37