APPENDIX: AIR QUALITY

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GUIDELINES FOR EVALUATING AIR QUALITY IMPACTS FROM PARKING GARAGES

For air quality purposes, a parking garage is defined as a parking facility that would be totally (or almost totally) enclosed. This type of facility would require mechanical ventilation to limit the carbon monoxide (CO) concentrations within the garage to levels less than those mandated by the New York City Building Code. Table 1 displays the estimated hourly average ins and outs over a 24-hour period for a proposed auto parking garage. A sample air quality analysis is also provided for potential air quality impacts from ventilated exhaust CO emissions for an auto parking garage. This analysis does not use the most up-to-date MOBILE program or related emission factors, but the methodology used is still applicable. A spreadsheet is available here that could be used for the garage analysis.

Page 3 of the Appendix displays all input parameters that are required to estimate the maximum CO emission rates and concentrations within the parking garage. CO emission factors and background values are reported at the top of the page. In almost all cases, maximum hourly CO emission rates within the facility will be calculated for the time period with the maximum number of departing autos in an hour, since departing autos should be assumed to be "cold" and arriving cars should usually be assumed to be "hot" as part of the recommended procedures for estimating CO emissions for parking facilities. ("Cold" autos emit CO at considerably higher rates than "hot" autos as shown by the CO emission factors listed). Likewise, maximum hourly CO emission rates over a consecutive 8-hour period will normally be computed for the 8-hour time period that averages the largest number of departing autos per hour. Maximum hourly and 8-hour average CO emission rates should be determined based on the ins/outs (for the respective time averaging periods) and the mean traveling distance within the garage. The analysis should also assume that all departing autos would idle for one minute before travelling to the exits of the garage, and all arriving and departing autos would travel at 5 mph within the garage. The equations and definitions of the parameters used to determine the emission rates exhausted through the vents and the maximum CO concentrations within the garage are also presented on page 1.

Page 4 of the Appendix displays the calculations involved in determining the off-site impacts from the CO exhausted through the garage vent(s). These estimates of off-site CO impacts are based on equations pertaining to the dispersion of pollutants from a stack (EPA's Workbook of Atmospheric Dispersion Estimates, AP-26, pg. 6, equations 3.3 and 3.4). The initial horizontal and vertical distributions, $\sigma_y(0)$ and $\sigma_2(0)$, respectively, should be assumed to be equal and calculated by setting the CO concentration at the exit of the vent equal to the CO level within the facility. The sample analysis displays the recommended procedures for estimating 8-hor CO impacts at a receptor near the vent (5 feet from the vent, 6 feet below the midpoint height of the vent) and at a receptor across a street on the far sidewalk from the vent (50 feet away, also 6 feet below the vent midpoint). Page 3 displays contributions from on-street CO emissions to the far sidewalk receptor in this example that were calculated conservatively with a factor (307.7) that yields the maximum predicted impacts (which could be calculated by refined mathematical modeling), when multiplied by the on-street CO emission rate in grams/meter-second. Cumulative CO concentrations at the far sidewalk should be calculated by adding together the contributions from the garage exhaust vent, on-street sources, and background levels. An acceptable alternative method to the procedures detailed above would be to use only the peak hourly CO emissions to calculate the CO emission rates and concentrations at the vent outlet. This alternative procedure would yield very conservative estimates of off-site CO impacts.

Air Quality Appendix Table 1
Garage Ins/Outs

HOUR	IN	OUT
12-1	1	1
1-2	1	0
2-3	0	0
3-4	0	0
4-5	0	1
5-6	1	5
6-7	5	8
7-8	7	9
8-9	14	31
9-10	17	8
10-11	18	11
11-12	15	12
12-1	31	32
1-2	14	11
2-3	10	10
3-4	10	11
4-5	13	16
5-6	35	30
6-7	17	20
7-8	13	10
8-9	9	6
9-10	1	2
10-11	1	0
11-12	1	0
Total	**234**	**234**

File: GARAGE.WQ1

Sample Mechanically Ventilated Parking Garage Analyses:

1997 Mobile 4.1 CO Emission Factors:

			1997 CO background
Cold Idle @ 45F	[CI]:	779.81 G/HR	1-HR 5.7 PPM
5mph Cold Auto @ 45F	[CA]:	143.08 G/MI	8-HR 2.8 PPM
5mph Hot Auto @ 45F	[HA]:	25.73 G/MI	

MAXIMUM HOUR PERIOD	INS (1997 INS/OUTS)	OUTS	MAXIMUM 8-HOUR PERIOD	INS	OUTS	GARAGE GSF	MEAN TRAV.DIS. (FEET)	PEAK HOURLY (G/SEC)	8-HR AVG. ER (G/SEC)	MAX 1-HR CONC.W/O BKGD (PPM)	PEAK 8-HR CONC.W/O BKGD (PPM)	MAX 1HR CONC.W/ BKGD (PPM)	MAX 8HR CONC.W/ BKGD (PPM)
12AM-1PM	31	32	11AM-7PM	16.1	17.8	48220	300	0.200	0.112	7.60	4.20	13.30	7.10

where: maximum hour is 1-hour period with largest number of autos departing

maximum 8-hour period is usually the 8-hour period with largest average number of departing autos over 8 hours

garage GSF - total gross square feet of garage area, where garage area does not include mechanical areas

mean travel distance - conservative estimate (about two thirds of the longest travel distance within the facility) of average travel distance for a typical vehicle entering/exiting the facility

Max 1-hour & 8-hour average ER - maximum hourly average CO emission rates within the facility for these respective time averaging periods

Max hour ER:

(max hr autos out)*((CI/60) + (CA)*(mean travel distance/5280))/3600 + (max hr autos ins)*HA*(mean travel distance)/(5280*3600)

8-hour average ER

(max 8-hr autos out)*((CI/60) + (CA)*(mean travel distance/5280))/3600 + (max 8 hr autos ins)*HA*(mean travel distance)/(5280*3600)

Max 1-hour & 8-hour concentration without background - CO concentrations calculated within the facility based on respective emission rates and New York City building code minimum ventilation rate of 1 cubic foot per minute per gross square feet of garage area for the respective time averaging periods

peak hour conc w/o bkgrd:

0.873*(peak hour ER)*1000/(GSF*0.000472)

8-hour average conc w/o bkgrd:

0.873*(8-hour ave ER)*1000/(GSF*0.000472)

Max 1-hour & 8-hour concentration - maximum 1 and 8-hour concentrations within garage when backgrounds are added to concentrations without backgrounds

Calculation of Cumulative Carbon Monoxide Impacts from Garage and Adjacent Street Emissions

ASSUMPTIONS: 2 Vents (since it is a relatively large garage, smaller garages may only warrant 1 vent)

Middle of Vent is 12' above local grade

Receptor height is 6', at a distance of 5' from vent

$\chi(0) = Q / \pi * \sigma_y(0) * \sigma_z(0)$

<u>1997</u>

8-HOUR CO ER PER VENT = 0.112/2 = 0.056 g/sec = Q
8-HOUR CO CONCENTRATION = 4.29 PPM = 0.0049 g/m^3
8-HOUR CO BKGD = 2.9 PPM
8-HOUR PERSISTENCE FACTOR - 8-HR PF = 0.70

Solve for initial horizontal + vertical distributions:

Let $\sigma_z(0) = \sigma_y(0)$

$$0.0049 = 0.056 / \pi * (\sigma_y(0))^2$$

Therefore $\sigma_y(0) = 1.9m$

at 5' (1.52m) from vent, 6'(H = 1.83m) below vent height:

$\sigma_y(1.52) = 0.16 * 1.52 + 1.9 = 2.14m$
$\sigma_z(1.52) = 0.14 * 1.52 + 1.9 = 2.11m$

$$\text{8-hr } \chi(1.52) = (\text{8-hr PF})*Q*(\exp(-0.5*(H/\sigma_z(1.52))^2)) / \pi * \sigma_y(1.52) * \sigma_z(1.52)$$

Therefore, $\chi(1.52) = 0.00190\ g/m^3 = 1.7$ PPM

at 50' (15.24m) from vent, 6'(H = 1.83m) below vent height:

$\sigma_y(15.24) = 0.16 * 15.24 + 1.9 = 4.3m$
$\sigma_z(15.24) = 0.14 * 15.24 + 1.9 = 4.0m$

$$\text{8-hr } \chi(15.24) = (\text{8-hr PF})*Q*(\exp(-0.5*(H/\sigma_z(15.24))^2))/\pi * \sigma_y(15.24) * \sigma_z(15.24)$$

Therefore, $\chi(15.24) = 0.000653\ g/m^3 = 0.6$ PPM

Highest On-Street Emissions

		g/mi-hr	g/m-sec
WB adjacent street		6423	0.00111
EB adjacent street		3272	0.00056
	Total	9695	0.00167

Maximum Impacts from line source:

307.7 * (8-hr Persistence Factor) * 0.00167 = 0.36 PPM

Total 8-hr CO Concentration
@ receptor on opposite sidewalk = 0.6 + 0.36 + 2.9 = 3.8 PPM

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GUIDELINES FOR EVALUATING AIR QUALITY IMPACTS FROM PARKING LOTS

For air quality purposes, a parking lot is defined as a parking facility that would be an at-grade lot, exposed to the ambient air. Table 1 displays the estimated hourly average ins and outs over a 24-hour period for a proposed auto parking lot. A sample air quality analysis is also provided in the attachment for potential air quality impacts from CO emissions emitted by an auto parking lot. This analysis does not use the most up-to-date MOBILE program or related emission factors, but the methodology used is still applicable.

Figure 1 displays the overall dimensions of a proposed parking lot. Page 1 of the attachment displays all input parameters that are required to estimate the maximum CO emission rates within the parking lots. In almost all cases, maximum hourly CO emission rates within the facility will be calculated for the time period with the maximum number of departing autos in an hour, since departing autos should be assumed to be "cold" and arriving cars should usually be assumed to be "hot" as part of the recommended procedures for estimating CO emissions for parking lots. ("Cold" autos emit CO at considerably higher rates than "hot" autos as shown by the CO emission factors listed). Likewise, maximum hourly CO emission rates over a consecutive 8-hour period will normally be computed for the 8-hour time period that averages the largest number of departing autos per hour. Maximum hourly and 8-hour average CO emission rates should be determined based on the ins/outs (for the respective time averaging periods) and the mean traveling distance within the facility. The analysis should also assume that all departing autos would idle for one minute before travelling to the exits of the lot, and all arriving and departing autos would travel at 5 mph within the parking lot. The equations and definitions of the parameters used to determine the emission rates within the parking areas are identical to those found in the "Guidelines for Evaluating Air Quality Impacts from Parking Garages."

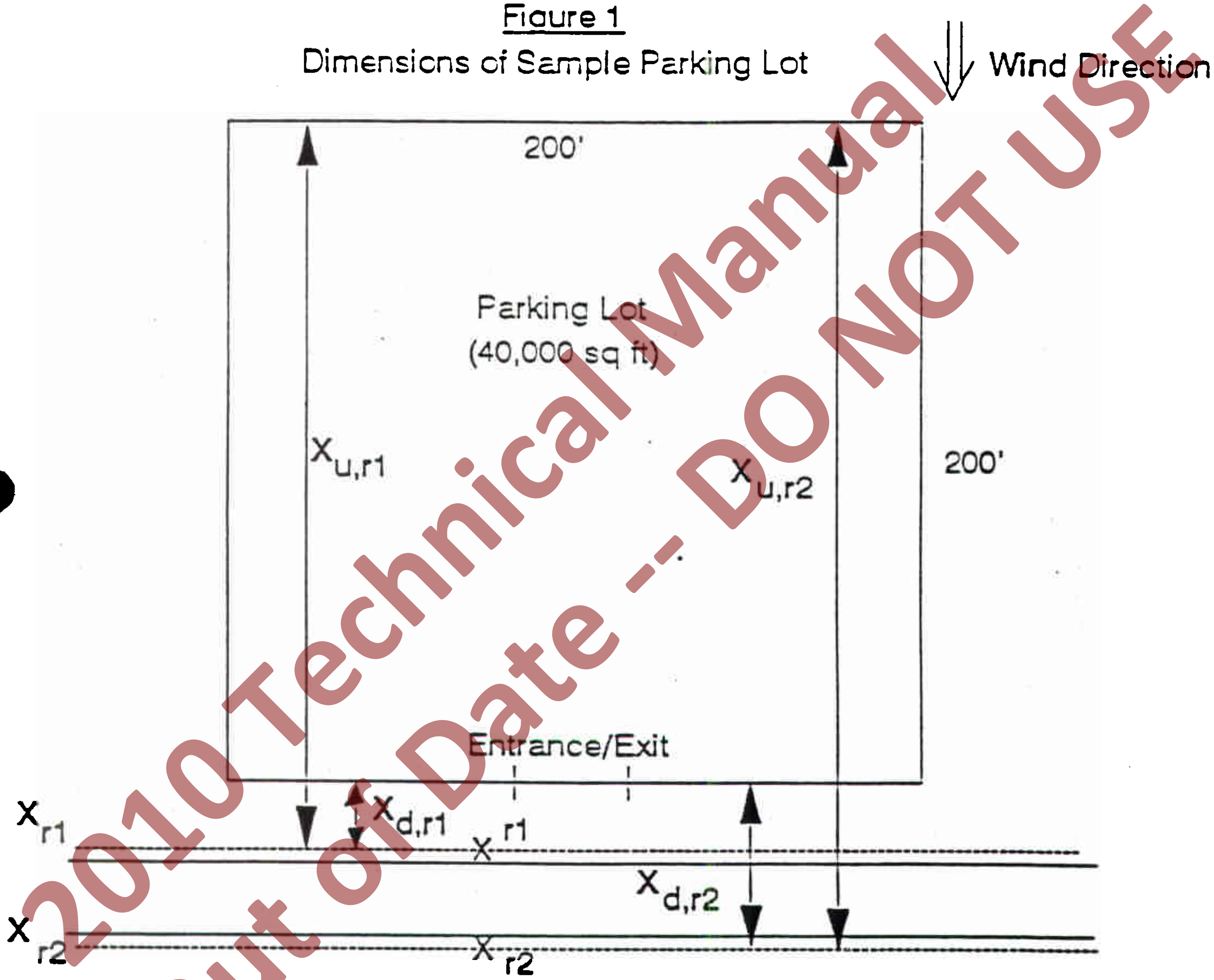
Equations 1, 2, and 3 display the calculations involved in determining the off-site impacts from CO emitted within the parking lot. These estimates of off-site CO impacts are based on EPA's guidelines pertaining to the dispersion of pollutants from a parking lot (*Guidelines for Air Quality Maintenance Planning and Analysis Volume 9 (Revised): Evaluating Indirect Sources*, pg.92, equations 35 and 36). Definitions of the various parameters in the equations area also provided on page 1 of the attachment. The sample analysis displays the recommended procedures for estimating 8-hour CO impacts at a pedestrian-height sidewalk receptor 6 feet from the lot and at a receptor across a street on the far sidewalk from the vent (62 feet away). On-street CO emissions contributions to the far sidewalk receptor in this example that were calculated conservatively with a factor (307.7) that yields the maximum predicted impacts (which could be calculated by refined mathematical modeling), when multiplied by the on-street CO emission rate in grams/meter-second. Cumulative CO concentrations at the far sidewalk should be calculated by adding together the contributions from the garage exhaust vent, on-street sources, and background levels. An acceptable alternative method to the procedures detailed above would be to use only the peak hourly CO emissions to calculate the CO emission rates within the facility and off-site 8-hour CO impacts. This alternative procedure would yield very conservative estimates of off-site CO impacts.

Air Quality Appendix Table 2
Garage Ins/Outs

HOUR	IN	OUT
12-1	1	1
1-2	1	0
2-3	0	0
3-4	0	0
4-5	0	1
5-6	1	5
6-7	3	8
7-8	26	10
8-9	69	20
9-10	16	3
10-11	10	5
11-12	10	5
12-1	13	20
1-2	7	8
2-3	16	19
3-4	28	34
4-5	30	81
5-6	36	40
6-7	24	29
7-8	16	19
8-9	9	7
9-10	1	3
10-11	1	1
11-12	1	0
Total	**319**	**319**

Figure 1

Dimensions of Sample Parking Lot



File: PARKLOT.WQ1

Sample Parking Lot Analyses:

1997 Mobile 4.1 CO Emission Factors:

Cold Idle @ 30F	[CI]:	1028.61 G/HR
5mph Cold Auto @ 30F	[CA]:	188.17 G/MI
5mph Hot Auto @ 30F	[HA]:	32.13 G/MI

1997 CO background
1-HR 5.7 PPM
8-HR 2.9 PPM

1997 INS/OUTS

MAXIMUM HOUR PERIOD	INS	OUTS	MAXIMUM 8-HOUR PERIOD	INS	OUTS	PARKING LOT GSF	MEAN TRAV.DIS. (FEET)	PEAK HOURLY ER (G/SEC)	8-HR AVG. ER (G/SEC)	Qa, 8-hr
4-5PM	30	81	12-8PM	21.3	31.3	40,000	201	0.557	0.219	0.000059

$$\chi u/Q_a = \frac{0.8}{a(1-b)}(r_u^{1-b} - r_d^{1-b}) * PF \quad (1)$$

$$r_u = x_u + x_o \quad (2)$$

$$r_d = x_d + x_o \quad (3)$$

where:

χ - 8-hour CO concentration from parking lot emissions (g/m^3)

u - wind speed (= 1 meter/sec)

Q_a - CO emissions in parking lot per unit area of lot (g/m^2-sec)

a,b - empirical constants (for almost all applications, a = 0.50, b = 0.77)

r_u - effective distance from the receptor to the upwind edge of the parking lot (meters)

r_d - effective distance from the receptor to the downwind edge of the parking lot (meters)

x_u - measured distance from the receptor to upwind edge of the parking lot (meters)

x_d - measured distance from the receptor to downwind edge of the parking lot (meters)

x_o - virtual distance used to affect an initial vertical mixing of CO emissions (x_o = 19.9m)

PF - 8-hour meteorological persistence factor (= 0.7)

Since $x_{u,r1} = 62.8m$ (206 ft) & $x_{d,r1} = 1.8m$ (6 ft)
$x_{u,r2} = 79.9m$ (262 ft) & $x_{d,r2} = 18.9m$ (62 ft)

Therefore $\chi_{r1} = 0.00021\ g/m^3 = 0.18$ PPM
$\chi_{r2} = 0.00016\ g/m^3 = 0.14$ PPM

8-hr Total CO Conc @ r1 = χ_{r1} + bkgrd = 0.18 + 2.9 = 3.08 PPM

		ER	
		g/mi-hr	g/m-sec
WB adjacent street		6423	0.00111
EB adjacent street		3272	0.00056
	Total	9695	0.00167

On-street = 307.7 * PF * ER = 0.36 PPM

8-hr Total CO Conc @ r2 = χ_{r2} + On-street + bkgrd = 0.14 + 0.36 + 2.9 = 3.4 PPM

GUIDELINES FOR EVALUATING AIR QUALITY IMPACTS FROM MULTILEVEL NATURALLY VENTILATED PARKING FACILITIES

A multi-level parking facility with at least 3 partially open sides is naturally ventilated by the ambient air. A sample air quality analysis is also provided in the Appendix for potential air quality impacts from CO emissions emitted by an auto parking lot. In this example, maximum hourly CO emissions will be used to conservatively estimate 8-hour CO impacts adjacent to the facility. The 5:00 p.m. to 6:00 p.m. period would have the largest number of departing autos and the largest hourly estimate of CO emissions in this sample analysis for a proposed 7-level naturally ventilated auto parking facility. This analysis does not use the most up-to-date MOBILE program or related emission factors, but the methodology used is still applicable.

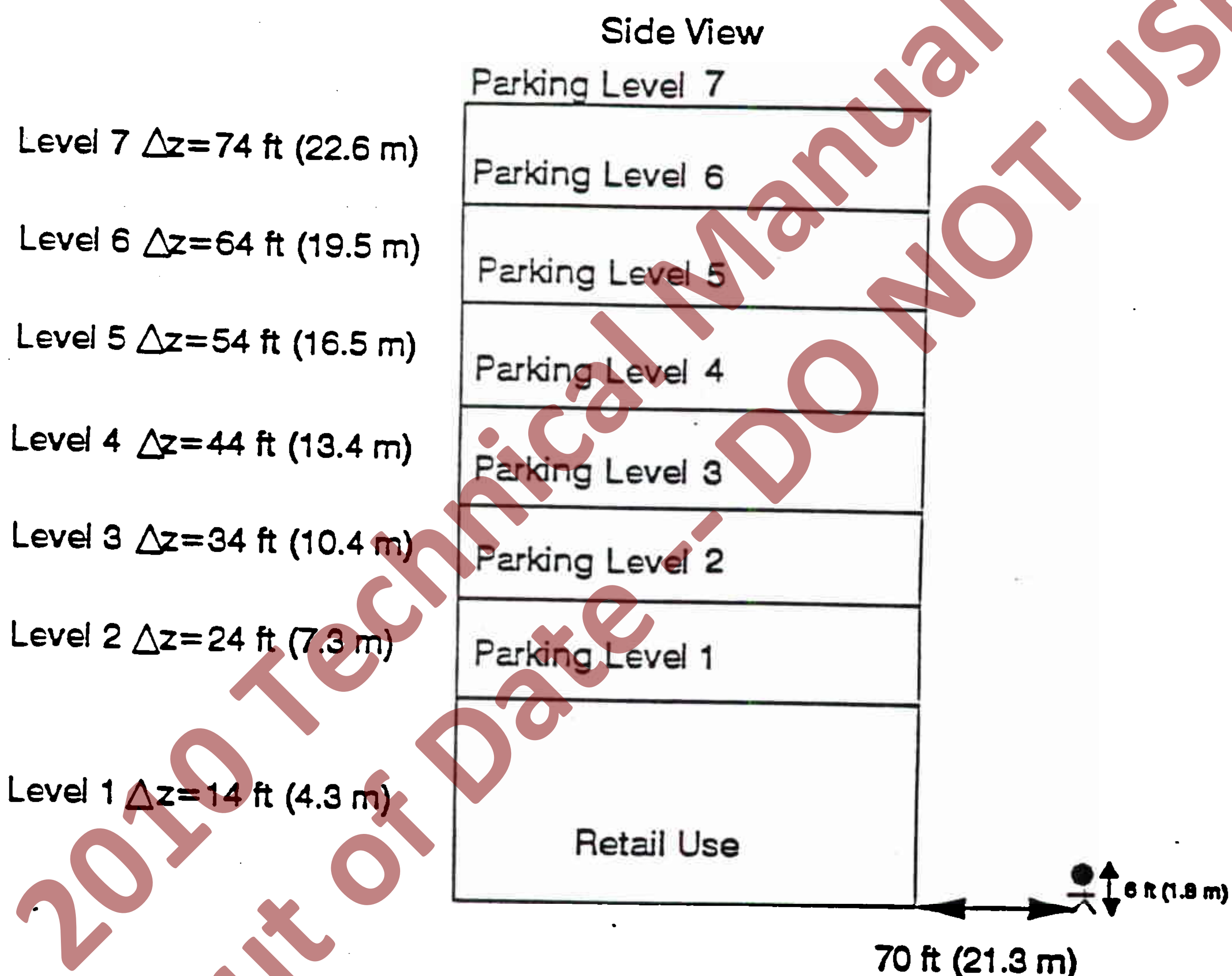
Figure 1 provides a side view of a sample 7-level open-side facility, which would be built above a retail use. Figure 2 displays a top view applicable to each parking level. The proposed facility would have several entrances and exits. Page 15 of this Appendix displays all input parameters that are required to estimate the maximum CO emission rates within the parking lots. CO emission factors and background values are reported at the top of the page. The analysis should also assume that all departing autos would idle for one minute before travelling to the exits of the lot, and all arriving and departing autos would travel at 5 mph within the parking lot. The equations and definitions of the parameters used to determine the emission rates within the parking areas are identical to those found in the "Guidelines for Evaluating Air Quality Impacts from Parking Garages."

Estimates of CO emissions rates for each level should consist of two components: vehicles arriving/departing the level, and "excess" vehicles that are passing through a level, destined toward a higher or lower parking level within the facility. In this example, the total number of autos traveling in and out of the structure in the 5:00 p.m. to 6:00 p.m. hour have been divided by the number of parking levels (*i.e.*, 7) to determine the average number of vehicles parking or leaving each level in this hour (*e.g.*, a total of 679 departure averages out to 97 departures per level). $Q_{a,\,lvl}$ represents the CO emissions estimates per unit area for vehicles originating from or destined for each level. Excess CO emissions for each level should be calculated based on the number of excess autos traversing through the parking level and the distance traveled by such vehicles. As shown in the example, the number of excess vehicles increases to a maximum at level 1. Q_{exc} represents the excess emissions per level, and $Q_{\mathrm{a\ exc}}$ is Q_{exc} divided by the floor area of the respective parking level. Q is defined as the total emission per unit area per level, and is the sum of $Q_{\mathrm{a\ exc}}$ and $Q_{a,\,lvl}$ for each parking level.

The sample analysis displays the recommended procedures for estimating 8-hour CO impacts at a pedestrian height sidewalk receptor 70 feet from the facility. Equations 1, 2, and 3 are the calculations involved in determining the off-site impacts from CO emitted from an at-grade parking lot. Equation 4 is the recommended correction factor to adjust CO impacts calculated with $Q_{a,\,lvl}$ and equation 1 (i.e., χ center line) for each parking level to a pedestrian height receptor. The equation for this height correction factor is based on the correction term for elevated point sources in EPA's *Workbook of Atmospheric Dispersion Estimates*, AP-26 (pg. 6, equation 3.3.). Height corrections factors for each level should be based on the difference between pedestrian height (6 feet) and the respective parking level elevation, and should be multiplied to the χ centerline calculated for each level. The table at the bottom of page 16 shows the result of these products for each level of the parking facility in this example. Page 3 displays on-street CO emissions contributions to the receptor in this example, which were calculated with a factor (307.7) that yields the maximum predicted impacts (which could be calculated by refined mathematical modeling), when multiplied by the on-street CO emission rate in grams/meter-second. Cumulative CO concentrations at this receptor should be calculated by adding together the contributions from the parking facility, on-street sources, and background levels.

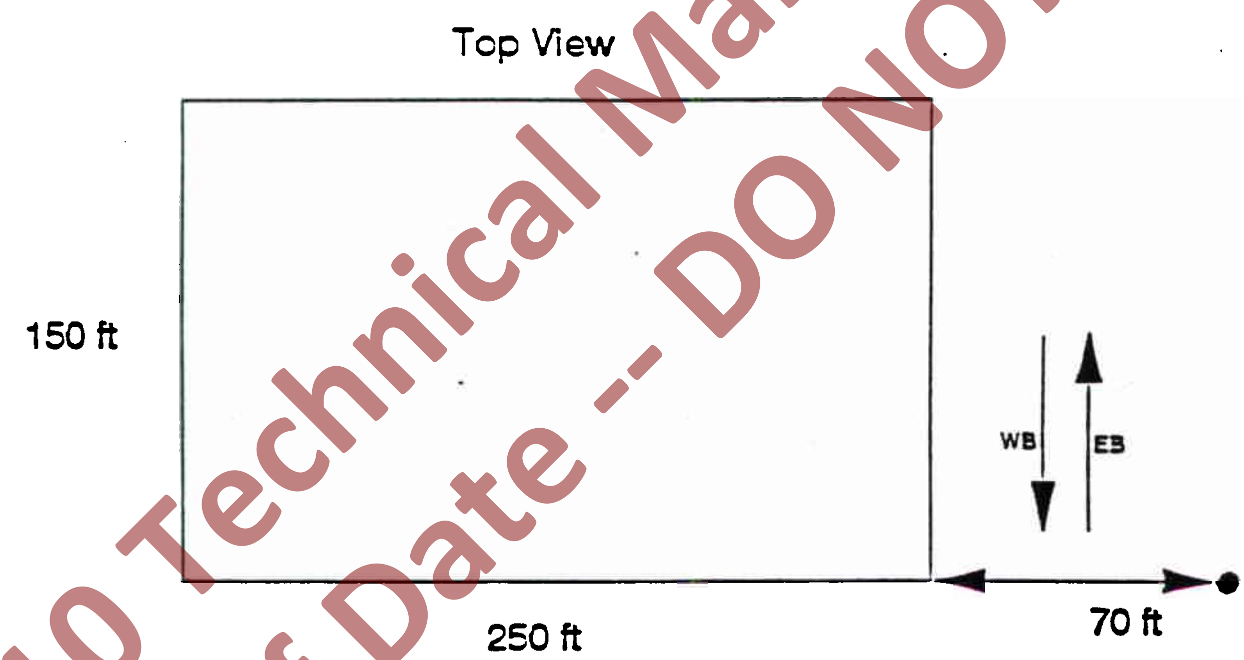
An acceptable alternative method to the procedures detailed above would be to use the hourly average CO emissions over the continuous 8-hour period with the largest CO emissions to calculate the CO emission rates within the facility and off-site 8-hour CO impacts. This alternative procedure should consider whether or not a larger proportion of vehicles would use the lower levels over an 8-hour average, as opposed to the equal averaging procedure used with the peak hourly emissions. The procedure employed in this sample analysis did not have to take this into account, since maximum hourly emissions were conservatively applied to estimate CO emission rates of an 8-hour period.

Figure 1



Side View
Parking Level 7
Level 7 Δz=74 ft (22.6 m)
Parking Level 6
Level 6 Δz=64 ft (19.5 m)
Parking Level 5
Level 5 Δz=54 ft (16.5 m)
Parking Level 4
Level 4 Δz=44 ft (13.4 m)
Parking Level 3
Level 3 Δz=34 ft (10.4 m)
Parking Level 2
Level 2 Δz=24 ft (7.3 m)
Parking Level 1
Level 1 Δz=14 ft (4.3 m)
Retail Use
6 ft (1.8 m)
70 ft (21.3 m)

Figure 2



Sample Multi-Level Naturally Ventilated Parking Facility Analysis:

1997 Mobile 4.1 CO Emission Factors:

Cold Idle @ 30F	[CI]:	1028.61	g/hr
5mph Cold Auto @ 30F	[CA]:	188.17	g/mi
5mph Hot Auto @ 30F	[HA]:	32.13	g/mi

1997 CO background
1-HR 5.7 PPM
8-HR 2.9 PPM

1997 INS/OUTS

MAXIMUM HOUR PERIOD	INS	OUTS	MAXIMUM HOUR PER LEVEL PERIOD	INS	OUTS	PARKING LOT GSF	MEAN TRAV.DIS. (FEET)	PEAK HOURLY ER PER LEVEL (G/SEC)	$Q_{a,lvl}$ (g/m^2-sec)
5-6PM	301	679	5-6PM	43	97	37,500	270	0.741	0.000213

Emissions from excess vehicles:

$$Q_{exc} = (N_{veh,dep} * [CA] * \Delta L + N_{veh,arr} * [HA] * \Delta L) / 3600$$

$$Q_{a,exc} = Q_{exc} / GSF$$

where: $N_{veh,dep}$ = number of excess departing autos from upper levels at each floor

$N_{veh,arr}$ = number of excess arriving autos from lower levels at each floor

ΔL = travel distance between floors (= 120 ft)

Level	Excess Vehicles Ins	Excess Vehicles Outs	Q_{exc}	$Q_{a,exc}$	$Q_{a,lvl}$	$Q_{a,tot}$
7	-	-	-	-	2.13×10^{-4}	2.13×10^{-4}
6	43	97	0.12	3.56×10^{-5}	2.13×10^{-4}	2.48×10^{-4}
5	86	194	0.25	7.12×10^{-5}	2.13×10^{-4}	2.84×10^{-4}
4	129	291	0.37	1.07×10^{-4}	2.13×10^{-4}	3.19×10^{-4}
3	172	388	0.50	1.42×10^{-4}	2.13×10^{-4}	3.55×10^{-4}
2	215	485	0.62	1.78×10^{-4}	2.13×10^{-4}	3.91×10^{-4}
1	258	582	0.74	2.13×10^{-4}	2.13×10^{-4}	4.26×10^{-4}

$$\chi u/Q_a = \frac{0.8}{a(1-b)}(r_u^{1-b} - r_d^{1-b}) * PF \quad (1)$$

$$r_u = x_u + x_o \quad (2)$$

$$r_d = x_d + x_o \quad (3)$$

with variables and constants as defined previously

Since x_u = 97.5m (320 ft) & x_d = 21.3m (70 ft),

Therefore $\chi u/Q_{a,tot} = 3.099$

Vertical Diffusion Correction:

$$\bar{x} = \exp(-0.5 * (\Delta z / \sigma_z)^2) \qquad (4)$$

where: $\bar{x}$ = correction factor for difference between height of each parking level and pedestrian height

σ_z = urban vertical dispersion coefficient for Pooler-McElroy stability class D

σ_z = 0.14 * x, where x is the distance between the edge of the parking area and the receptor site (in meters)

Δz = difference in height between parking lot level and pedestrian height (= 6 ft)

since x = 70 ft = 21.3 m,

therefore σ_z = 2.98 and

$$\bar{x} = \exp(-0.5 * (\Delta z / 2.98)^2)$$

Level	Δz (ft)	Δz (m)	$\bar{x}$
1	14	4.3	0.35
2	24	7.3	0.050
3	34	10.4	0.0023
4	44	13.4	0.000041
5	54	16.5	≈ 0
6	64	19.5	≈ 0
7	74	22.6	≈ 0

Level	$Q_{a,tot}$	χ Center Line	$\bar{x}$	g/m3 @ receptor	PPM	PF*PPM
7	2.13×10^{-4}	0.00066	≈ 0	≈ 0	0.000	0.000
6	2.48×10^{-4}	0.00077	≈ 0	≈ 0	0.000	0.000
5	2.84×10^{-4}	0.00089	≈ 0	≈ 0	0.000	0.000
4	3.19×10^{-4}	0.00100	0.000041	$4.08E \times 10^{-8}$	0.000	0.000
3	3.55×10^{-4}	0.00111	0.0023	$2.55E \times 10^{-6}$	0.002	0.001
2	3.91×10^{-4}	0.00122	0.05	$6.09E \times 10^{-5}$	0.053	0.037
1	4.26×10^{-4}	0.00133	0.35	$4.65E \times 10^{-4}$	0.407	0.285
					total	$0.32 = \chi_{tot}$

		ER	
		g/mi-hr	g/m-sec
WB adjacent street		6423	0.00111
EB adjacent street		3272	0.00056
	Total	9695	0.00167

On-street = 307.7 * PF * ER = 0.36 PPM

8-hr Total CO Conc = χ_{tot} + On-street + bkgrd = 0.32 + 0.36 + 2.9 = 3.6 PPM

GUIDELINES FOR PERFORMING VEHICLE CLASSIFICATION SURVEYS FOR AIR QUALITY ANALYSES

Collection of vehicle classification data for use in an air quality analysis should be performed according to the following general guidelines, to provide accurate and adequate descriptions of the vehicle mix required by the MOBILE models used to estimate emissions from motor vehicles. To get the most accurate estimate of traffic conditions, vehicle classification data should be taken concurrently with other traffic data collection efforts. Vehicle classification surveys should be performed at or near any sites where mobile source air quality analyses are performed.

1. Three good days of surveys for the midweek AM, midday (if necessary), and PM peak periods. Field surveyors should distinguish among autos, taxis, light duty trucks, heavy duty gas trucks, and heavy duty diesel vehicles. Buses should be considered to be heavy duty diesel vehicles.
2. If a weekend air quality analysis is required, surveys should be performed for at least one day for the weekend peak hour.
3. Field observers should use the following criteria to distinguish between light-duty trucks and heavy duty trucks:
    a. Light-duty trucks: vans, ambulances, pickup trucks, all trucks with 4 wheels.
    b. Heavy-duty trucks: basically all vehicles with 6 or more wheels. (Note: six wheels can be on 2- or 3-axle vehicles).
    c. The field observer should be acquainted with the stacks associated with heavy-duty diesel trucks in order to distinguish them from heavy duty gas trucks. Light-duty gas trucks should be divided into two groups (LDGT 1 and LDGT 2) based on local registration data. The registered split between LDGT 1 and LDGT 2 is 73 percent to 27 percent, respectively, at the time these guidelines were prepared. DEC or DEP can be contacted to determine if this split (73/27) is still appropriate.
4. The percentage of taxis for each link could be divided into fleet medallion (FM) and non-fleet medallion (NFM) taxis based on the ratio between FM and NFM listed in DEP's Report #34 (approximately 3 FM for every 1 NFM). Since field observers usually cannot distinguish between non-medallion (NM) taxis and private autos when taking surveys, the NM taxi fraction as listed in Report #34 could be subtracted from the auto fractions for each link, or instead, the NM taxi fraction could be treated as autos in the emissions calculations. The emissions for light-duty gas autos can then be calculated using the latest approved MOBILE model with these four distinct classifications (autos, FM, NFM, and NM taxis).
5. Raw survey counts should be summed by vehicle type. The average vehicle classification for the street corridor during the respective peak period should be based upon the summed values and the relative percentages among the vehicle types.

GUIDELINES FOR CALCULATING RECIRCULATION FOR CHEMICAL SPILLS

To assess impacts from accidental chemical spills under a laboratory fume hood, effects from recirculation must be addressed. If an exhaust vent is located near operable windows or air intake vents, there is potential for recirculation of the pollutant back into the building.

The potential for recirculation is assessed using the method described by D.J. Wilson in *A Design Procedures for Estimating Air Intake Contamination from Nearby Exhaust Vents*, ASHRAE TRAS 89, Part 2A, p. 136-152 (1983). This procedures takes into account such factors as plume momentum, stack-tip downwash, and cavity recirculation effects. This recirculation analysis determines worst-case minimum dilution between exhaust and air intake.

Three separate effects produce the available dilution: internal system dilution (mixing in plenum chamber of multiple exhaust streams and fresh air); wind dilution, dependent on the distance from the vent to intake and the exit velocity; and dilution from stack, caused by stack height and plume rise from vertical exhaust velocity. The critical wind speed is dependent on exit velocity, distance from vent to intake, and the cross-sectional area of the exhaust stack.

The following information about the pollutant and exhaust system must be known: stack height (m), stack diameter (m), stack exit velocity (m/s), mass flow rate of pollutant (g/sec), molecular weight of pollutant (g/mol), and the stretched string distance from the stack to the nearest receptor.

An example recirculation for carbon tetrachloride is included in the attachment. The inputs are: molecular weight of carbon tetracholoride, assumed mass flow rate, assumed stack diameter, height and exit velocity, and assumed string distance between stack and nearby receptor.

10/23/01

ASHRAE Dilution Calculations for Potential Spill
Carbon Tetrachloride

DTOTAL= DSYSTEM * DWIND * DSTACK

Diameter	=	3.26	ft
Actual stack height	=	11	ft
exit velocity	=	24.38	m/s

DILUTION OF SYSTEM (DSYSTEM): CALCULATED AS TOTAL CONCENTRATION EXITING STACK

DSYSTEM= (flowrate/(velocity per stack) x 1000 x 24.45 / mol wt)

flowrate of carbon tetrachloride	=	0.9635	g/sec
molecular wt of carbon tetrachloride	=	154	

DSYSTEM= 6.3 PPM

DILUTION OF WIND (DWIND)=((1+1.48(S/@SQRTAe)^.5)^2 **(from ASHRAE)**

WHERE S = STRING DISTANCE FROM STACK TO NEAREST RECEPTOR = 189 FT
Ae = X-SECTIONAL AREA OF EXHAUST STACK (PI*D^4/4) = 8.35 FT^2

THEREFORE DWIND = 168.2

DILUTION FROM STACK (DSTACK) (BETA=1 FOR UNCAPPED, VERTICAL EXHAUST) **(from ASHRAE)**

Ucrit/Ve=20 x (sqrtAe)/S = 0.31

Therefore, Ve/Ucrit= 3.27 >1.5 so Hd = 0

Hd=2*diameter*(1.5-Ve/Ucrit)= 0.00 FT

Hs=actual stack height - Hd = 11.00 FT

DSTACK= exp((4.23*hs/s+.707*beta)^2) = 2.5

THUS, DTOTAL = 0.015 PPM

GUIDELINES FOR CALCULATING EVAPORATION RATE FOR CHEMICAL SPILLS

In order to calculate evaporation rate from an accidental chemical spill, the following physical properties must be known: boiling point (deg C), molecular weight (g/mol), density (g/cm^3), and vapor pressure (mm Hg).

The recommended procedures to determine the evaporation rate are displayed in the sample calculations provided in the attachment. Equations 1 and 3 are based on the Shell Model (Fleischer, M.T., *An Evaporation/Air Dispersion Model for Chemical Spills on Land*, Shell Development Company (Dec. 1980). Equations 2, 4, and 5 are based on *Mass Transfer Operations, 3rd Edition*, by R.E. Treybal, p. 31-33.

The evaporation rate, E, is dependent on the diffusivity of the component through air and saturated vapor density, among other factors. The diffusivity, D (equation 2), is based on several factors including a collision function that must be obtained from Figure 2.5 in *Mass Transfer Operations*, p. 32. The saturation vapor density, ρ*, is calculated from the ideal gas law: PV = nRT. Room temperature (20 C) and an air flow rate of 0.5 m/s are assumed for calculation of evaporation rate.

An example evaporation rate calculation for acetone is included in the attachment. Note that this example is limited by the size of the lab. A spill area of 0.25 m^2 is assumed.

LAB SPILL ANALYSIS - EVAPORATION RATE

Sample Calculation for Acetone

Evaporation Rate

$E = D_{c\text{-}a} * Sh_L * (1/L) * (\rho^*)$ eq. (1)

where Dc-a is the diffusivity of component "c" through air, and defined as:

$$D_{c\text{-}a} = \frac{10^{-4} * (1.084 - 0.249\ \text{sqrt}(1/M_c + 1/M_a)) * T^{3/2} * \text{sqrt}(1/M_c + 1/M_a)}{P_t * (r_{ca})^2 * f(kT/E_{ca})} \quad \text{eq. (2)}$$

M_c, M_a are molecular weights of compound "c" and air, respectively [kg/kmol]

T = room temperature = 293 K

P_t = 1 std atm = 101.3×10^3 N/m^2

E_{ca} = energy of molecular attraction

r_{ca} = molecular separation at collision [nm]

$r_A = 1.18\ v^{1/3}$ (r in nm)

v = MW / Density (v in m^3/kmol)

$r_{AB} = (1.3711 + r_A) / 2$ (r_{AB} in nm)

$$v \to \frac{(g/mol) * (1000\ mol / 1\ kmol)}{(g/cm^3) * (100\ cm / 1\ m)^3} \to m^3/kmol$$

$E_A / k = 1.21 * T_b$

$E_{AB} / k = \text{sqrt}(78.6 * (E_A / k))$

$f(kT/E_{AB})$ ---> estimate from Figure 2.5 on page 32 of *Mass Transfer Operations*

$$D_{acetone-air} = \frac{10^{-4} * (1.084 - 0.249\ \text{sqrt}(1/58 + 1/29)) * (293)^{3/2} * \text{sqrt}(1/58 + 1/29)}{(101.3 \times 10^3)(0.4331)^2 (0.56)}$$

$= 1.10 \times 10^{-5}$ m^2/sec

ρ^* = saturated vapor density

$\rho^* = n/V = P/RT$

Ideal Gas Law: PV = nRT

R = Gas Constant = 0.082 L atm / mol K

$$\rho^* = \frac{180\ mmHg\ (1\ atm / 760\ mmHg)}{(0.082\ L\ atm / mol\ K)(293\ K)}$$ (vapor pressure of acetone = 180 mmHg)

$= 9.86 \times 10^{-3}$ mol/L or 9.86×10^{-6} mol/cm^3

$(9.86 \times 10^{-3}$ mol/L$) * (1000$ L / 1 m$^3) * (58$ g/mol acetone)

$\rho^* = 572$ g/m^3

Sh_L = Sherwood # = $0.664\ S_c^{1/3}\ Re_L^{1/2}$ eq. (3)

where S_c = Schmidt # = $\mu / (\rho * D_{c\text{-}a}) = \upsilon_{air} / D_{c\text{-}a}$ eq. (4)

[μ = viscosity, ρ = density, $D_{c\text{-}a}$ = diffusivity, υ = kinematic viscosity (at 21 degrees C and std atm)]

$Re_L = vL/\upsilon$ eq. (5)

[L = length, v = velocity of wind = 0.5 m/sec]

$Sh_{acetone} = (0.664) * (1.482 \times 10^{-5}\ m^2/sec / 1.10 \times 10^{-5}\ m^2/sec)^{1/3} * [(0.5\ m/sec)(0.5\ m) / (1.482 \times 10^{-5}\ m^2/sec)]^{1/2}$

= 95.2

$E_{acetone} = (1.10 \times 10^{-5}\ m^2/sec)\ (95.2)\ (1 / 0.5\ m)\ (572)$

= 1.1980 g/m^2.sec = evaporation rate for acetone

Emission Rate

Based on a spill area of 0.25 m^2, Q = Emission Rate

E x A = 1.1980 g/m^2.sec x 0.25 m^2 = 0.299 g/sec

References

Eq (1), (3) from Shell Model
Eq (2), (4), (5) from *Mass Transfer Operations*, 3rd Ed., by Treybal

Calculation of Evaporation Rate from Chemical Spill

23-Oct-01

Name	Container Size (liters)	Tb (C)	MW (g/mol)	d (g/cm^3)	r (nm)	E/(kT)	<r> (nm)	<E/(kT)>	<(kT)/E>	f(<>)	D (m^2/s)	P at 20C (mm Hg)	ro (g/m^3)	Evaporation Rate (g/m^2-s)
Example														
Acetone		56.2	58	0.7857	0.4950	1.3603	0.4331	0.6041	1.6554	0.56	1.10E-05	180	572	**0.8480**

REFINED SCREENING ANALYSES FOR HEAT AND HOT WATER SYSTEMS

Section 322.1 in Chapter 17, "Air Quality," provides a discussion which identifies that impacts from boiler emissions are a function of fuel type, stack height, minimum distance from the source to the nearest receptor (building), and square footage of development resulting from the project. The preliminary screening analysis outlined in Section 322.1 to determine a project's potential for significant impacts (Figure 17-3) is based on use of No #6 fuel oil in a residential building, the most conservative, 'worst case' scenario. If more detailed information regarding the boiler characteristics is available, then a more accurate screen can be performed.

These screens in the manual and appendices are based on emission factors obtained from EPA's, Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources (http://www.epa.gov/ttn/chief/ap42) and fuel consumption data obtained from the Department of Energy (www.eia.doe.gov/emeu/recs and www.eia.doe.gov/emeu/cbecs/contents.html).

Appendix Figures 17-1 to 17-8 were specifically developed through detailed mathematical modeling to predict the threshold of development size below which a project would not likely have a significant impact based on the type of fuel, use of the proposed building(s), and distance to nearest building of a height similar to or greater than the stack height of the proposed building(s). In order to provide the most conservative screens for development size, NO_2 screens have been developed for fuel oil No. 6 and natural gas systems while SO_2 screens are provided for systems based on fuel oil No. 2 and No. 4. The step-by-step methodology outlined below explains how to use these figures. Similar to the screen described in 322.1, this methodology is only appropriate for single buildings or sources. It is also only appropriate for buildings at least 10 meters (approximately 33 feet) from the nearest building of similar or greater height.

1. Consider the type of fuel that would be used to provide heat/hot water. If the type of fuel is unknown, generally assume No. 4 fuel oil (a conservative assumption for air quality purposes).
2. Determine the maximum size and type of development that would use the boiler stack. For residential or mixed-use commercial and residential projects, refer to the figures indicating "residential development." For non-residential uses, refer to the "commercial and other non-residential development" figures.
3. Using Geographic Information Systems (GIS), a Borough President's map, Sanborn atlas, or equivalent, determine the minimum distance (in feet) between the building(s) resulting from or facilitated by the proposed project and the nearest building of similar or greater height.
4. If this distance is less than 33 feet, more detailed analyses than this step-by-step screen are required. If the distance is greater than 400 feet, assume 400 feet.
5. Determine the stack height of the building resulting from the proposed project, in feet above the local ground level. If unknown, assume 3 feet above the roof height of the building.
6. Select from the heights of 30, 100, and 165 feet, the number closest to but NOT higher than the proposed stack height.
7. Based on steps 1 through 6 above, select the appropriate Appendix Figure for the proposed project:
    a. Appendix Figure 17-1: Residential Development, Fuel Oil #6, NO_2
    b. Appendix Figure 17-2: Commercial and Other Non-Residential Development, Fuel Oil #6, NO_2
    c. Appendix Figure 17-3: Residential Development, Fuel Oil #4, SO_2
    d. Appendix Figure 17-4: Commercial and Other Non-Residential Development, Fuel Oil #4, SO_2
    e. Appendix Figure 17-5: Residential Development, Fuel Oil #2, SO_2
    f. Appendix Figure 17-6: Commercial and Other Non-Residential Development, Fuel Oil #2, SO_2
    g. Appendix Figure 17-7: Residential Development, Natural Gas, NO_2

h. Appendix Figure 17-8: Commercial and Other Non-Residential Development, Natural Gas, NO_2

Locate a point on the appropriate chart by plotting the size of the development against the distance in feet to the edge of the nearest building of height similar to or greater than the stack of the proposed project.

If the plotted point is on or above the applicable curve, there is the potential for a significant air quality impact from the project's boiler(s), and detailed analyses may need to be conducted. If the plotted point is below the relevant curve, a potential significant impact due to boiler stack emissions is unlikely and no further analysis is needed.

In some cases, it may be possible to pass this screening analysis by restricting the type of fuel that could be used to supply heat and hot water. As illustrated in figures 17-1 through 17-8, No. 4 and No. 6 oils have greater emissions than No. 2 oil or natural gas. Limiting the fuel used by the proposed project to No. 2 oil or natural gas may eliminate the potential for significant adverse impacts and also the need for further analyses. This can be determined using steps 1 through 6 above. The project, however, would have to include the restriction on the boiler fuel type (and indicate the mechanism that would ensure the use of a specific fuel type) if this option is selected.

Alternatively, if a proposed project fails the initial screening analysis, but the maximum short-term 24-hour emissions of sulfur dioxide (for oil burning facilities) and annual emissions of nitrogen dioxide (for oil and gas burning facilities) have been estimated, Figures 17-9 and 17-10 can be used to determine the project's potential for significant impacts. Additionally, if the quantity of fuel consumption is known, the maximum short-term emissions can be calculated using EPA's AP-42 emission tables. For example, if the daily quantity of #6 fuel oil to be used is 100 gallons, the grams per second emissions can be calculated as follows:

$$\frac{100\ gallons}{day} \times \frac{0.0471\ lb}{gallon} \times \frac{453.59\ grams}{lb} \times \frac{1\ day}{86{,}400\ seconds} = \frac{0.025\ grams}{second}$$

The emission factor for SO2 for #6 fuel oil was obtained from EPA's AP-42, assuming 0.3 percent sulfur content. If the plotted point is on or above the curve corresponding to the appropriate stack height at the proper distance, there is the potential for a significant air quality impact from the project's boiler(s), and detailed analyses may need to be conducted. If the plotted point is below the applicable curve, a potential significant impact due to boiler stack emissions is unlikely and no further analysis is needed. For the above example, figure 17-10 indicates that for a proposed project that burns 100 gallons of #6 fuel oil daily and has a 100 foot stack, further analysis is necessary if there are any buildings within a distance of 60 feet.

FIG App 17-1

NO_2 BOILER SCREEN

RESIDENTIAL DEVELOPMENT - FUEL OIL #6

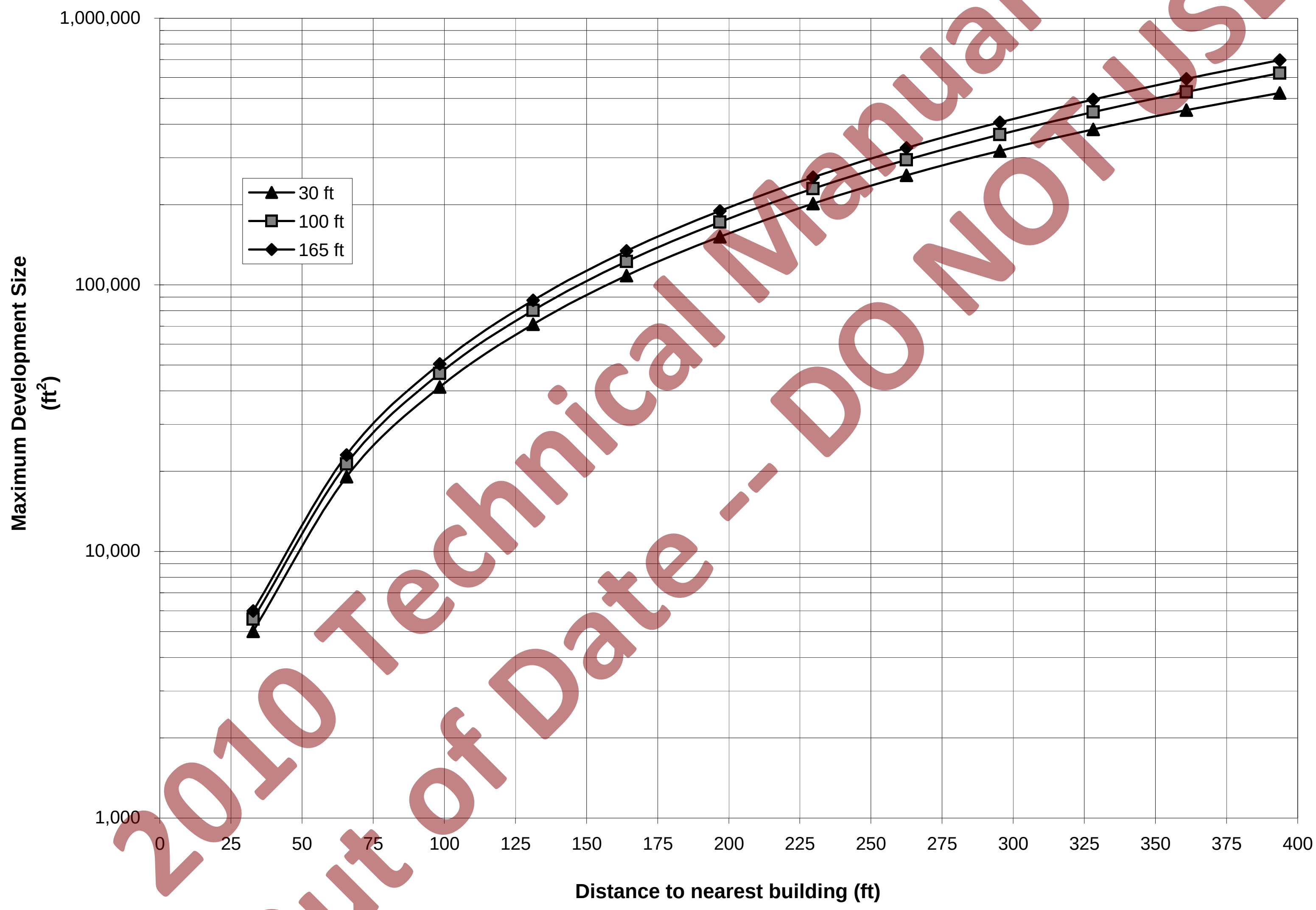


FIG App 17-2

NO_2 BOILER SCREEN

COMMERCIAL AND OTHER NON-RESIDENTIAL DEVELOPMENT - FUEL OIL #6

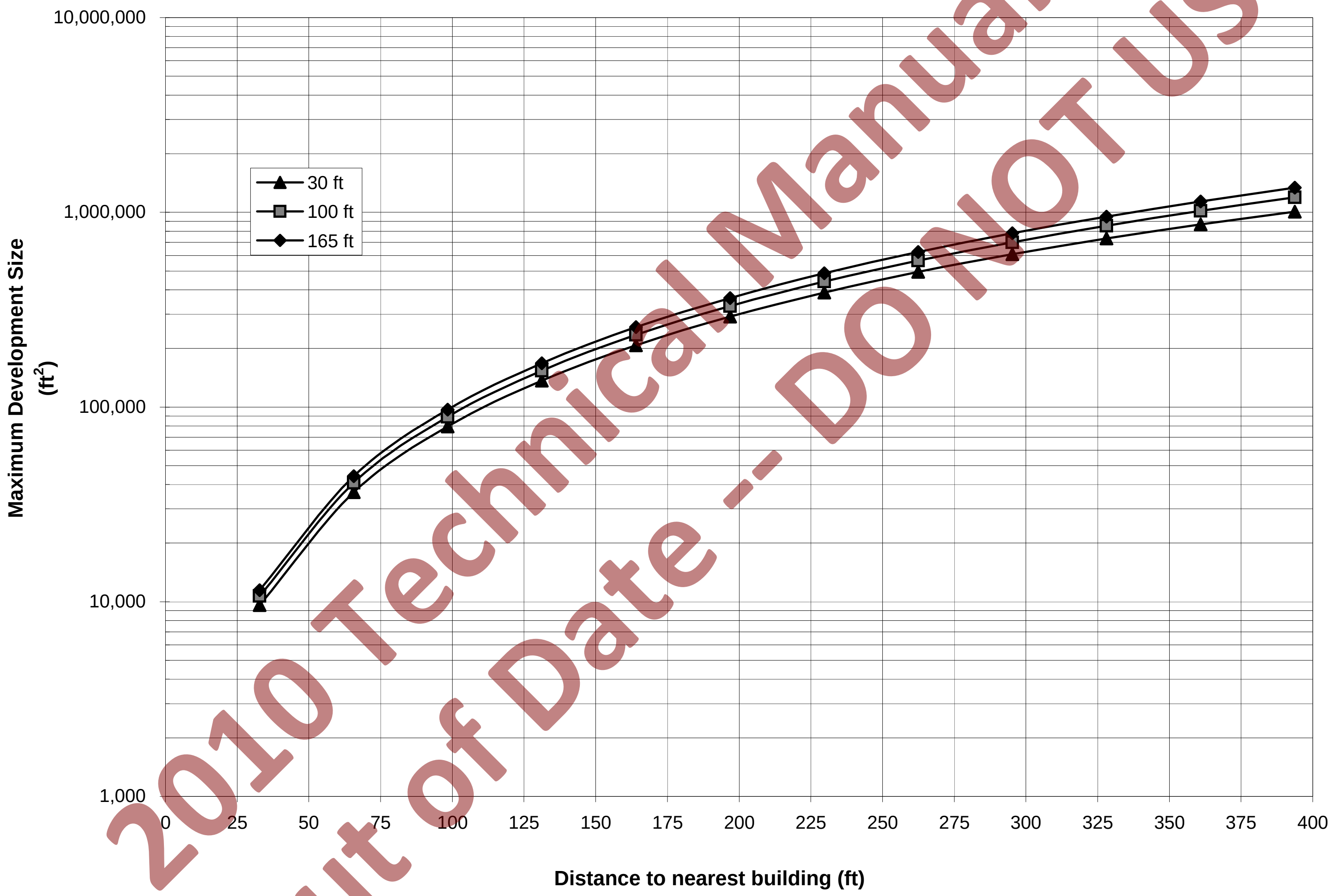


FIG App 17-3
SO_2 BOILER SCREEN
RESIDENTIAL DEVELOPMENT - FUEL OIL #4

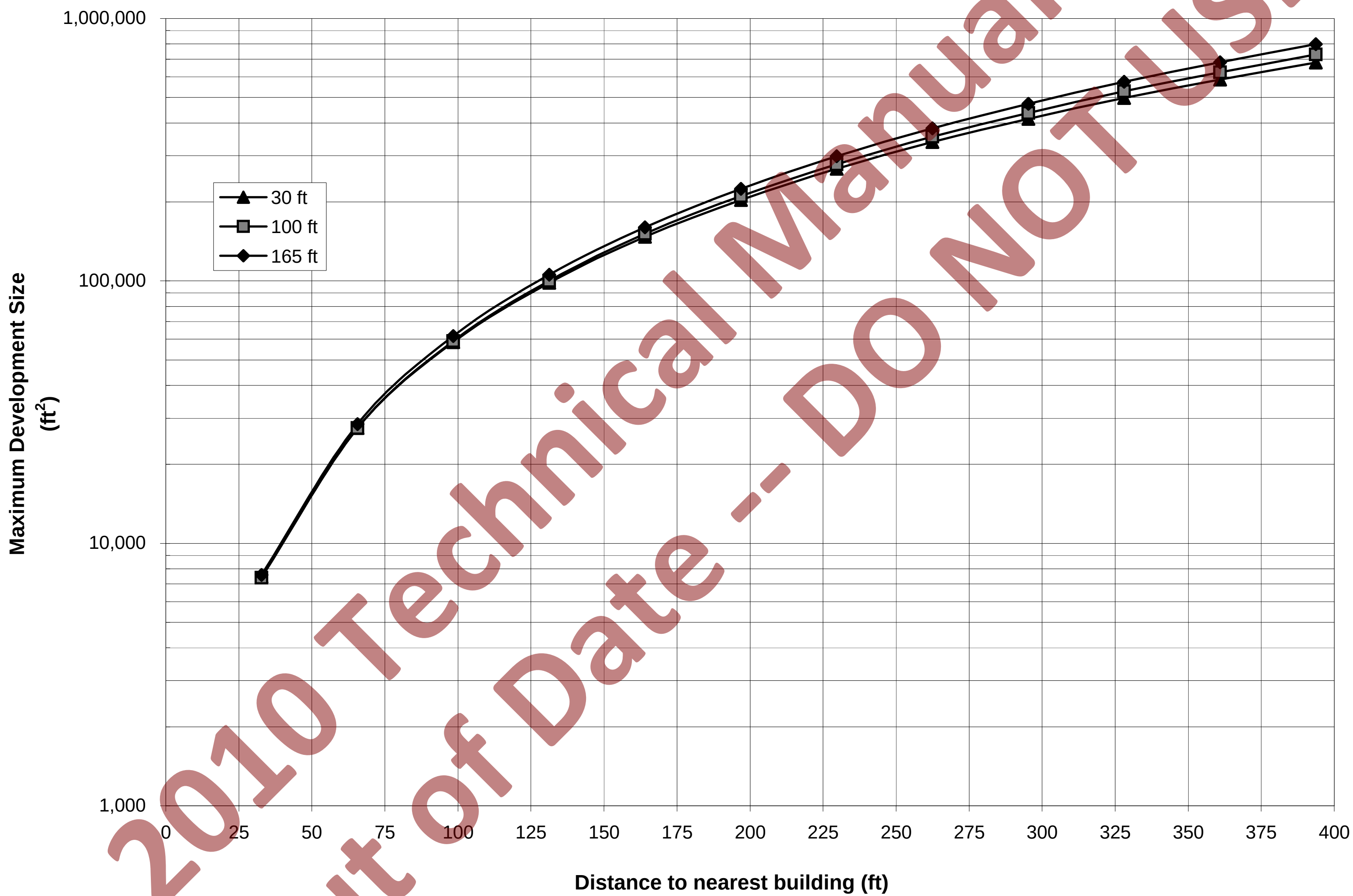


FIG App 17-4
SO_2 BOILER SCREEN
COMMERCIAL AND OTHER NON-RESIDENTIAL DEVELOPMENT - FUEL OIL #4

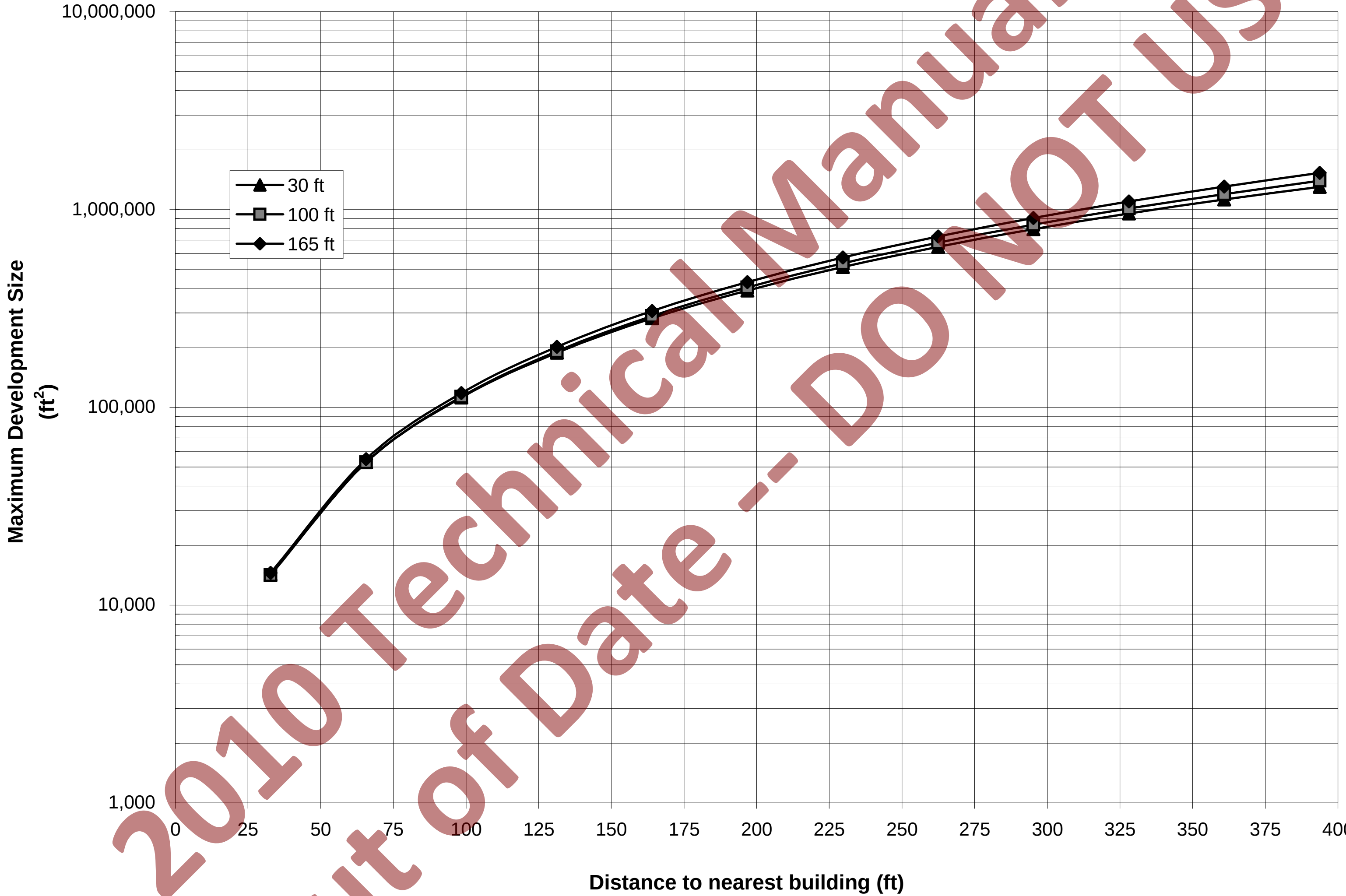


FIG App 17-5

SO_2 BOILER SCREEN

RESIDENTIAL DEVELOPMENT - FUEL OIL #2

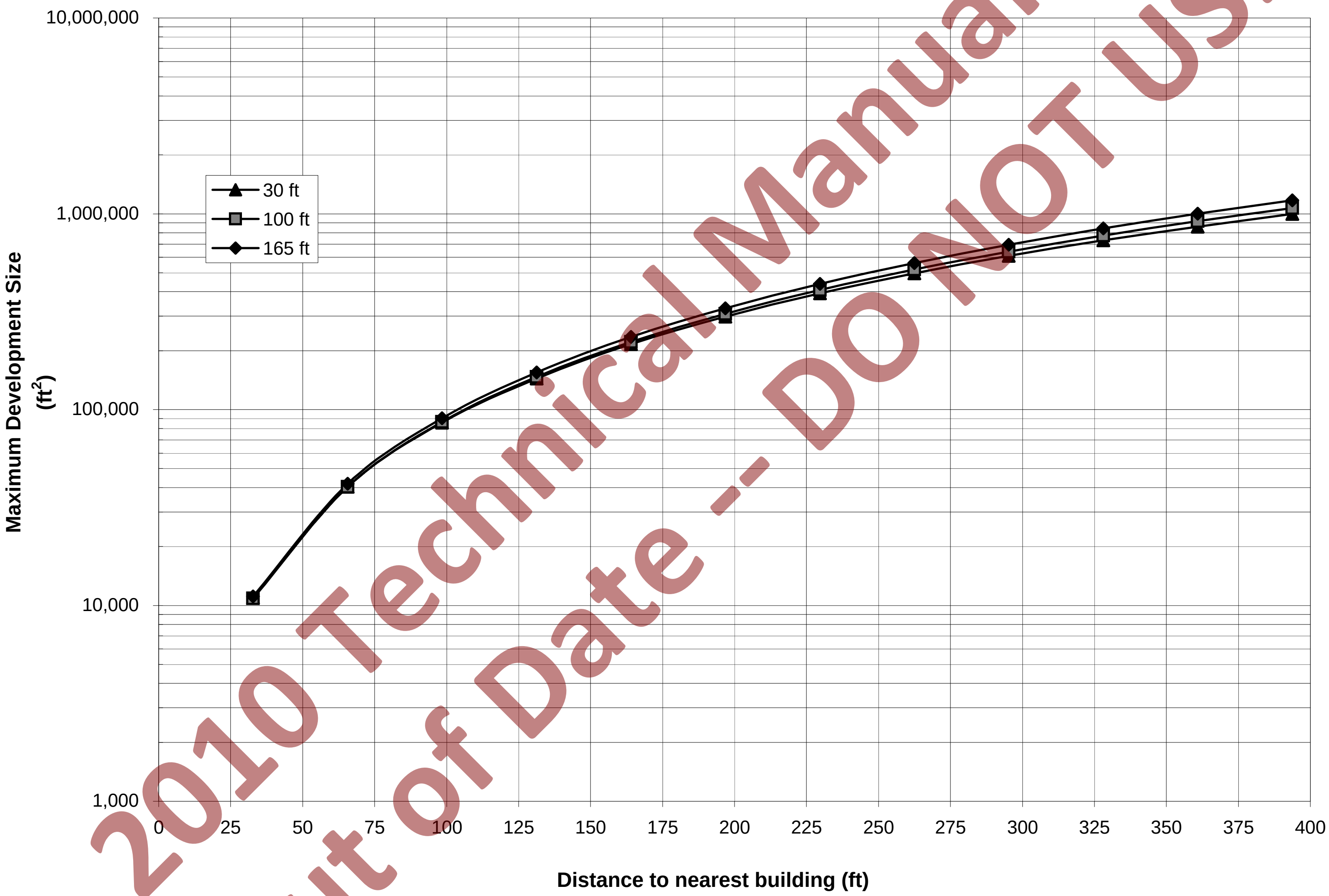


FIG App 17-6

SO_2 BOILER SCREEN

COMMERCIAL AND OTHER NON-RESIDENTIAL DEVELOPMENT - FUEL OIL #2

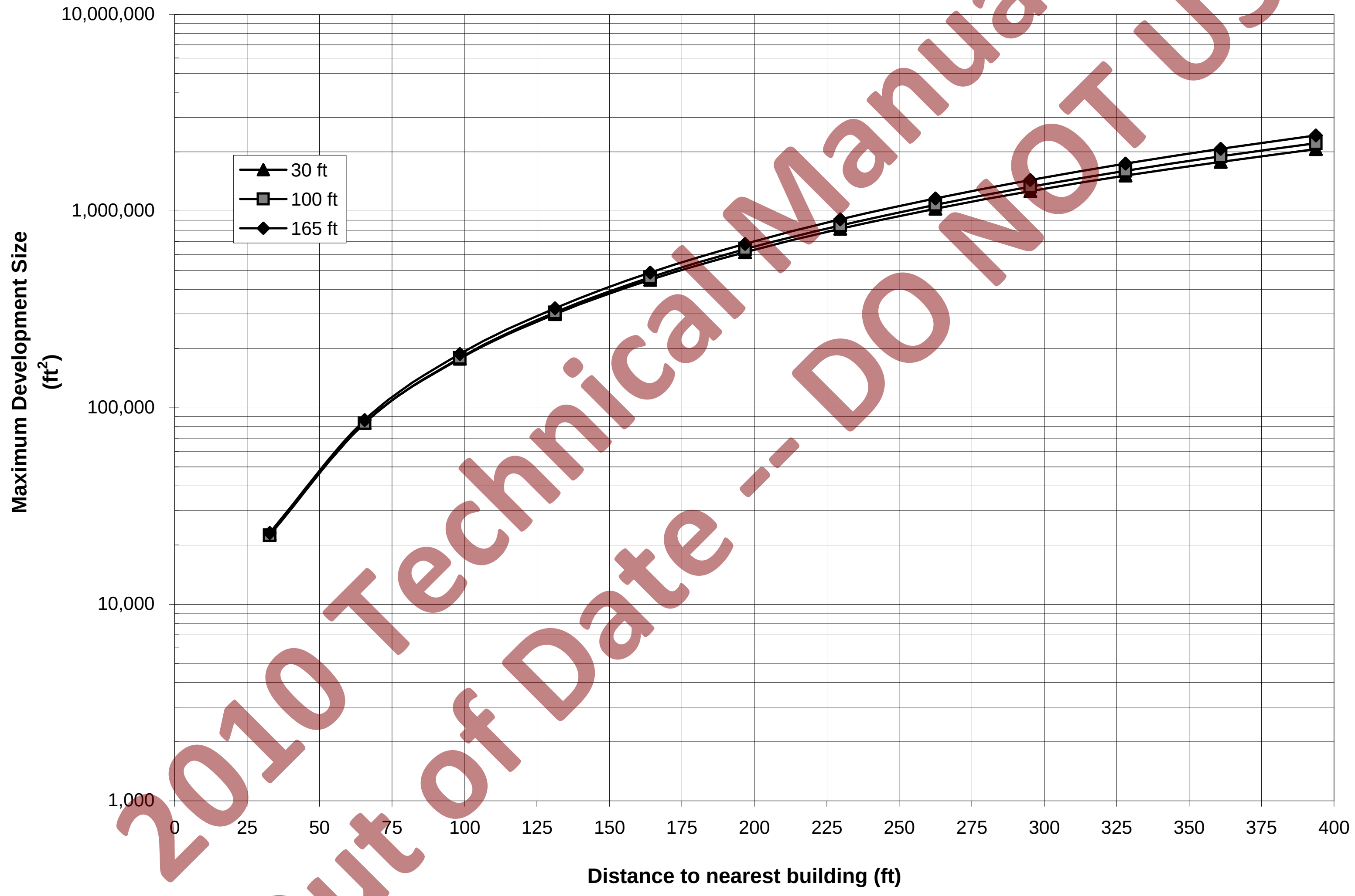


FIGURE 17-7
NO_2 BOILER SCREEN
RESIDENTIAL DEVELOPMENT - NATURAL GAS

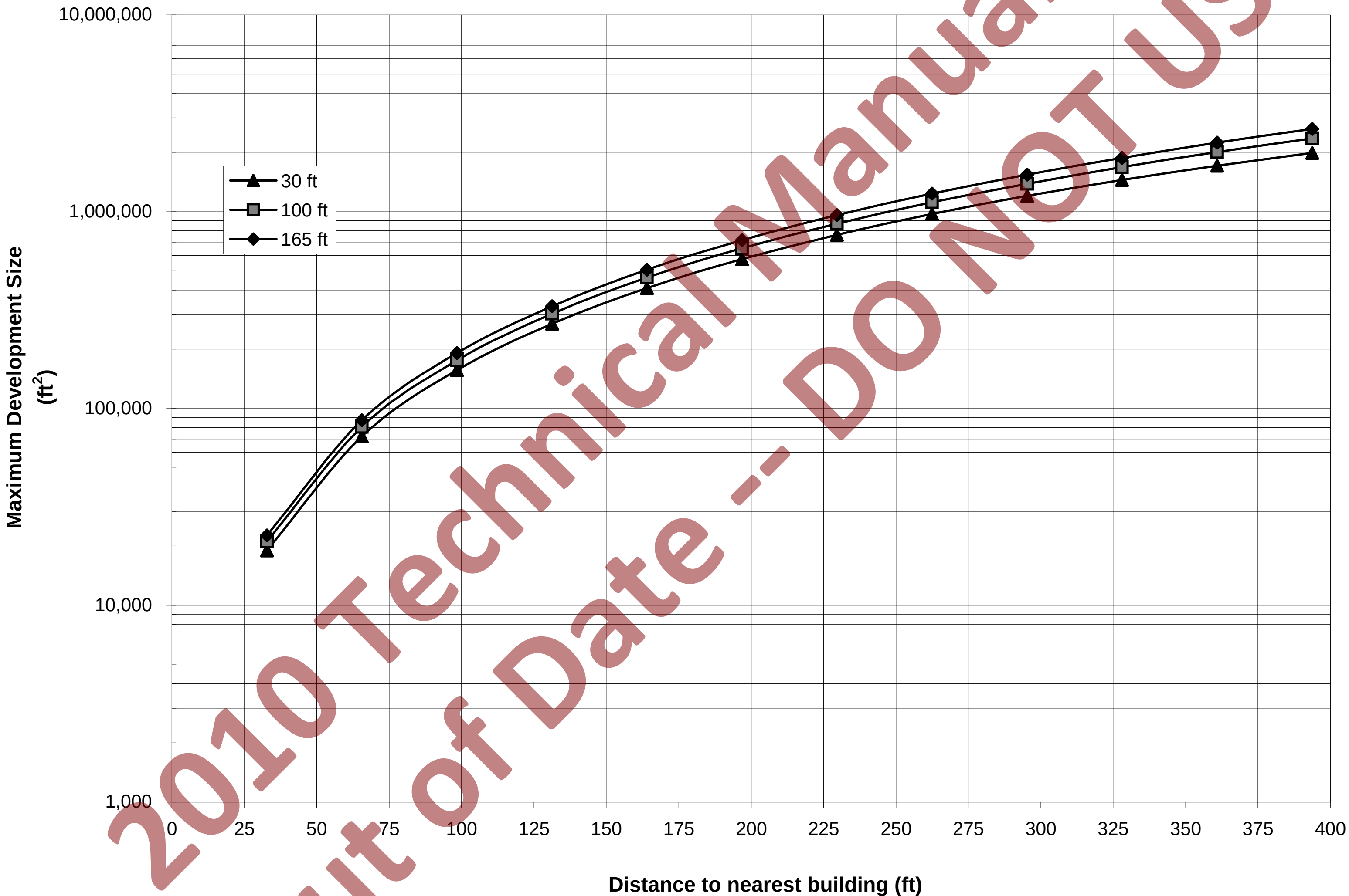


FIG App 17-8
NO_2 BOILER SCREEN
COMMERCIAL AND OTHER NON-RESIDENTIAL DEVELOPMENT - NATURAL GAS

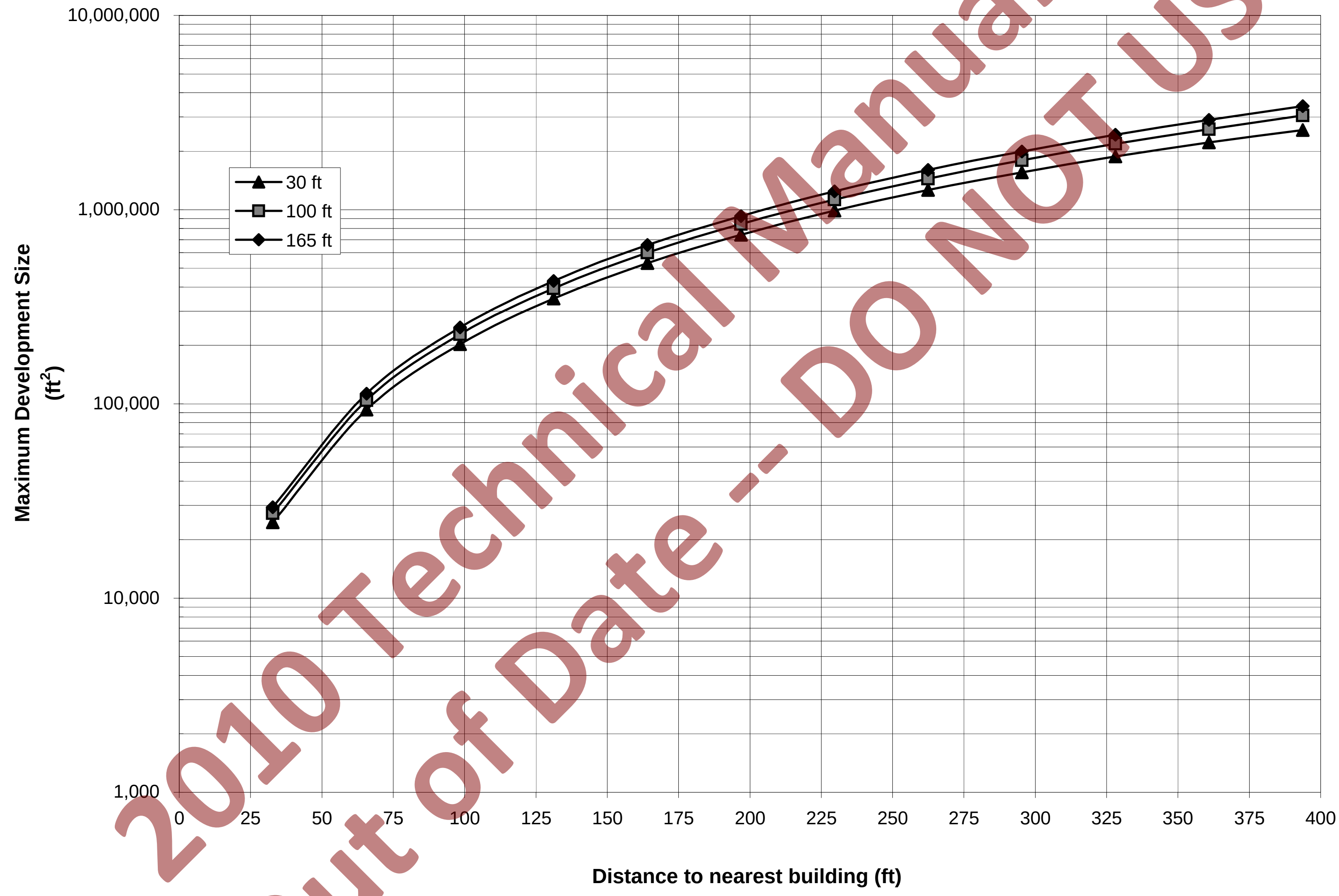


FIG App 17-9
NO_2 EMISSIONS BOILER SCREEN (annual)

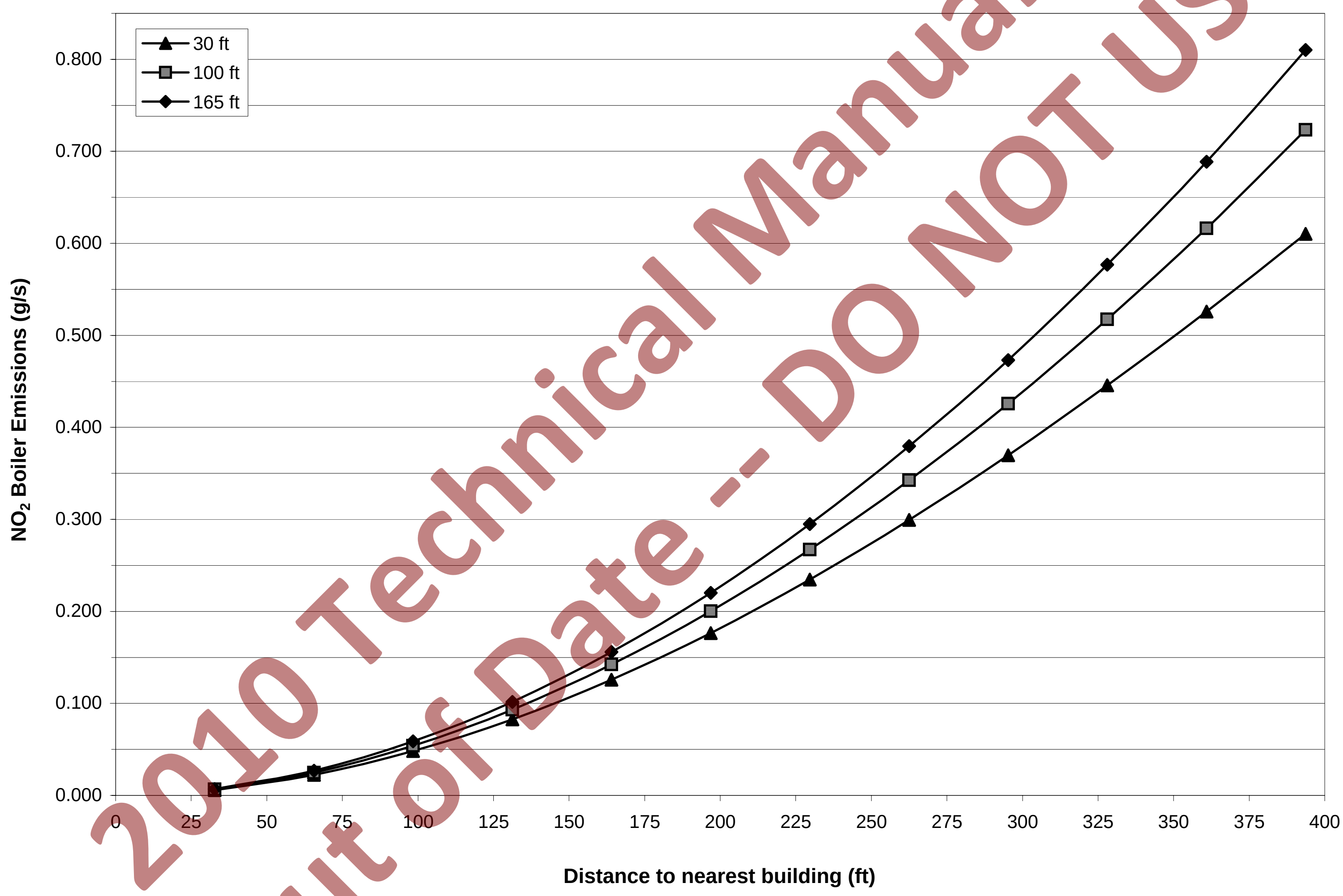


FIG App 17-10

SO_2 EMISSIONS BOILER SCREEN (24-hour)

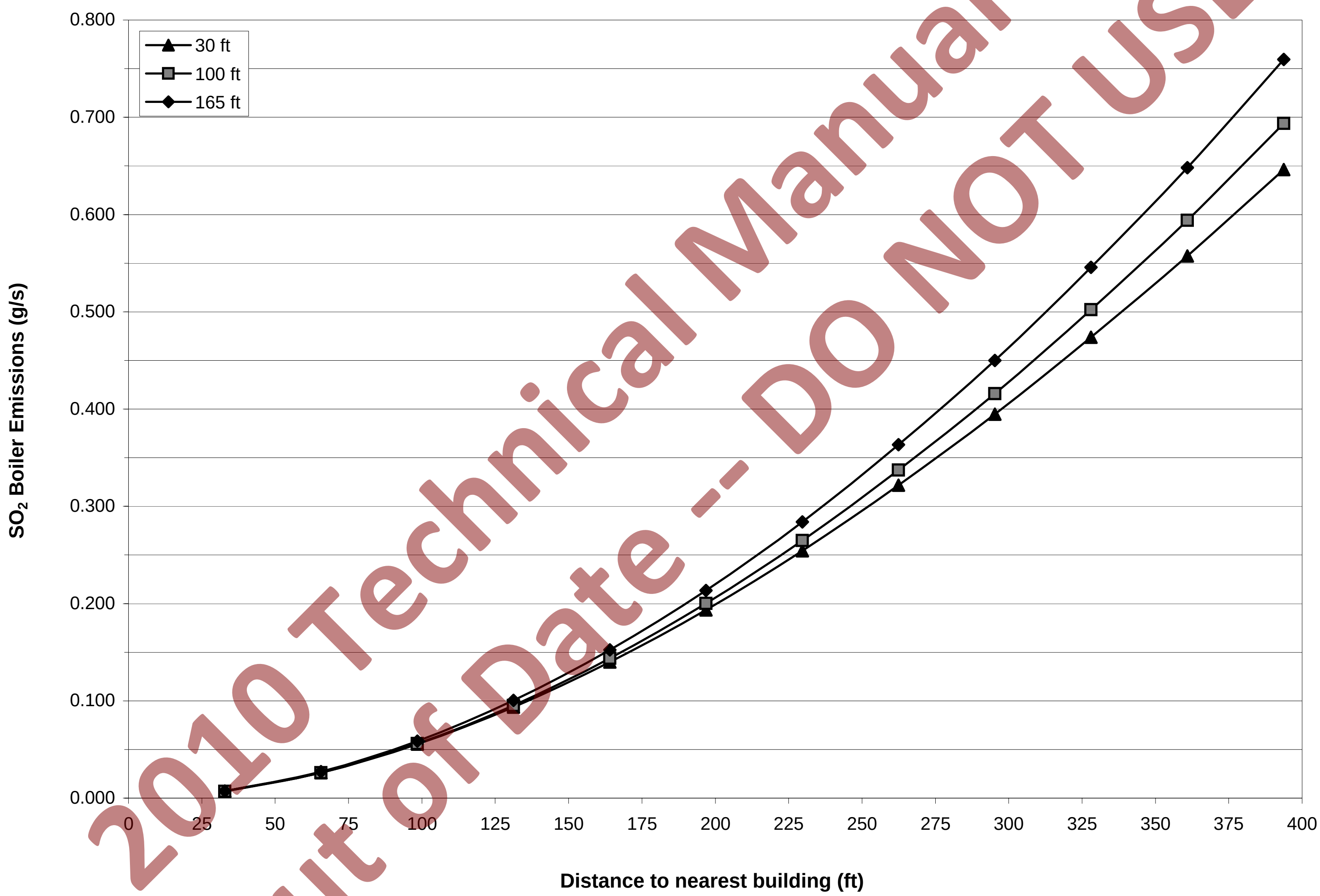


Table 1.3-1. CRITERIA POLLUTANT EMISSION FACTORS FOR FUEL OIL COMBUSTION[a]

Firing Configuration (SCC)[a]	SO_2[b]		SO_3[c]		NO_x[d]		CO[e]		Filterable PM[f]	
	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING
Boilers > 100 Million Btu/hr										
No. 6 oil fired, normal firing (1-01-004-01), (1-02-004-01), (1-03-004-01)	157S	A	5.7S	C	47	A	5	A	9.19(S)+3.22	A
No. 6 oil fired, normal firing, low NO_x burner (1-01-004-01), (1-02-004-01)	157S	A	5.7S	C	40	B	5	A	9.19(S)+3.22	A
No. 6 oil fired, tangential firing, (1-01-004-04)	157S	A	5.7S	C	32	A	5	A	9.19(S)+3.22	A
No. 6 oil fired, tangential firing, low NO_x burner (1-01-004-04)	157S	A	5.7S	C	26	E	5	A	9.19(S)+3.22	A
No. 5 oil fired, normal firing (1-01-004-05), (1-02-004-04)	157S	A	5.7S	C	47	B	5	A	10	B
No. 5 oil fired, tangential firing (1-01-004-06)	157S	A	5.7S	C	32	B	5	A	10	B
No. 4 oil fired, normal firing (1-01-005-04), (1-02-005-04)	150S	A	5.7S	C	47	B	5	A	7	B
No. 4 oil fired, tangential firing (1-01-005-05)	150S	A	5.7S	C	32	B	5	A	7	B
No. 2 oil fired (1-01-005-01), (1-02-005-01), (1-03-005-01)	157S	A	5.7S	C	24	D	5	A	2	A
No.2 oil fired, LNB/FGR, (1-01-005-01), (1-02-005-01), (1-03-005-01)	157S	A	5.7S	A	10	D	5	A	2	A

S=.2

157 x 0.2 = 31.4

http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s03.p

Table 1.3-1. (cont.)

Firing Configuration (SCC)[a]	SO_2[b] Emission Factor (lb/10^3 gal)	SO_2[b] EMISSION FACTOR RATING	SO_3[c] Emission Factor (lb/10^3 gal)	SO_3[c] EMISSION FACTOR RATING	NO_x[d] Emission Factor (lb/10^3 gal)	NO_x[d] EMISSION FACTOR RATING	CO[e] Emission Factor (lb/10^3 gal)	CO[e] EMISSION FACTOR RATING	Filterable PM[f] Emission Factor (lb/10^3 gal)	Filterable PM[f] EMISSION FACTOR RATING
Boilers < 100 Million Btu/hr										
No. 6 oil fired (1-02-004-02/03) (1-03-004-02/03)	157S	A	2S	A	55	A	5	A	10	B
No. 5 oil fired (1-03-004-04)	157S	A	2S	A	55	A	5	A	9.19(S)+3.22	A
No. 4 oil fired (1-03-005-04)	150S	A	2S	A	20	A	5	A	7	B
Distillate oil fired (1-02-005-02/03) (1-03-005-02/03)	142S	A	2S	A	20	A	5	A	2	A
Residential furnace (A2104004/A2104011)	142S	A	2S	A	18	A	5	A	0.4[g]	B

[a] To convert from lb/10^3 gal to kg/10^3 L, multiply by 0.120. SCC = Source Classification Code.

[b] References 1-2,6-9,14,56-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.

[c] References 1-2,6-8,16,57-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.

[d] References 6-7,15,19,22,56-62. Expressed as NO_2. Test results indicate that at least 95% by weight of NO_x is NO for all boiler types except residential furnaces, where about 75% is NO. For utility vertical fired boilers use 105 lb/10^3 gal at full load and normal (>15%) excess air. Nitrogen oxides emissions from residual oil combustion in industrial and commercial boilers are related to fuel nitrogen content, estimated by the following empirical relationship: lb NO_2/10^3 gal = 20.54 + 104.39(N), where N is the weight % of nitrogen in the oil. For example, if the fuel is 1% nitrogen, then N = 1.

[e] References 6-8,14,17-19,56-61. CO emissions may increase by factors of 10 to 100 if the unit is improperly operated or not well maintained.

[f] References 6-8,10,13-15,56-60,62-63. Filterable PM is that particulate collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. Particulate emission factors for residual oil combustion are, on average, a function of fuel oil sulfur content where S is the weight % of sulfur in oil. For example, if fuel oil is 1% sulfur, then S = 1.

[g] Based on data from new burner designs. Pre-1970's burner designs may emit filterable PM as high as 3.0 lb/10^3 gal.

Released: Dec 2006
Next CBECS will be conducted in 2007

Table C35. Fuel Oil Consumption and Conditional Energy Intensity by Census Region for Non-Mall Buildings, 2003

	Total Fuel Oil Consumption (million gallons)				Total Floorspace of Buildings Using Fuel Oil (million square feet)				Fuel Oil Energy Intensity (gallons/square foot)			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
All Buildings*	1,265	170	104	63	6,080	2,832	4,122	2,123	0.21	0.06	0.03	Q
Building Floorspace (Square Feet)												
1,001 to 10,000	381	Q	Q	Q	757	Q	255	Q	0.50	Q	0.10	Q
10,001 to 100,000	375	63	Q	Q	1,704	643	833	351	0.22	0.10	Q	Q
Over 100,000	509	20	44	Q	3,618	1,983	3,034	1,673	0.14	0.01	0.01	Q
Principal Building Activity												
Education	282	Q	Q	Q	933	Q	Q	Q	0.30	Q	Q	Q
Health Care	Q	Q	17	7	Q	492	786	262	Q	Q	0.02	0.03
Office	105	6	14	1	1,379	714	1,235	748	0.08	0.01	0.01	0.00
All Others	837	Q	44	40	3,426	1,281	1,644	984	0.24	Q	0.03	Q
Year Constructed												
1945 or Before	555	Q	Q	Q	2,126	Q	Q	Q	0.26	Q	Q	Q
1946 to 1959	277	Q	Q	Q	1,233	343	Q	Q	0.22	Q	Q	Q
1960 to 1969	Q	Q	Q	Q	579	398	443	Q	0.34	Q	Q	Q
1970 to 1979	121	Q	25	Q	626	562	693	Q	0.19	Q	0.04	Q
1980 to 1989	45	Q	Q	5	620	Q	1,064	980	0.07	Q	Q	0.01
1990 to 2003	Q	18	Q	6	896	806	1,184	325	0.08	0.02	Q	Q
Climate Zone: 30-Year Average												
Under 2,000 CDD and --												
More than 7,000 HDD	295	Q	N	Q	1,009	1,158	N	331	0.29	0.13	N	Q
5,500-7,000 HDD	398	20	N	Q	2,207	1,461	N	Q	0.18	0.01	N	Q
4,000-5,499 HDD	Q	Q	Q	Q	2,863	Q	1,392	Q	0.20	Q	Q	Q
Fewer than 4,000 HDD	N	N	29	Q	N	N	1,245	1,092	N	N	0.02	Q
2,000 CDD or More and --												
Fewer than 4,000 HDD	N	N	6	Q	N	N	1,486	Q	N	N	0.00	Q
Number of Floors												
One	230	35	Q	Q	987	420	800	311	0.23	0.08	Q	Q
Two	390	Q	Q	Q	1,249	603	618	Q	0.31	Q	Q	Q
Three	234	Q	Q	Q	916	Q	Q	Q	0.26	Q	Q	Q
Four to Nine	328	Q	41	Q	1,704	1,007	887	503	0.19	Q	0.05	Q
Ten or More	Q	Q	6	1	1,224	Q	1,349	900	Q	Q	0.00	0.00
Number of Workers (main shift)												
Less than 10	436	Q	33	Q	1,221	374	376	Q	0.36	Q	0.09	Q
10 to 99	606	27	Q	Q	2,501	939	988	Q	0.24	0.03	Q	Q
100 or More	222	16	39	Q	2,358	1,520	2,758	1,681	0.09	0.01	0.01	Q
Weekly Operating Hours												
48 or fewer	441	Q	Q	Q	1,426	475	559	Q	0.31	Q	0.05	Q
49 to 84	374	Q	Q	10	1,859	915	1,526	805	0.20	Q	Q	0.01
85 to 168	450	33	45	31	2,795	1,442	2,037	1,209	0.16	0.02	0.02	Q

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, C, and E of the 2003 Commercial Buildings Energy Consumption Survey. http://www.eia.doe.gov/emeu/cbecs

Released: Dec 2006
Next CBECS will be conducted in 2007

Table C25. Natural Gas Consumption and Conditional Energy Intensity by Census Region for Non-Mall Buildings, 2003

	Total Natural Gas Consumption (billion cubic feet)				Total Floorspace of Buildings Using Natural Gas (million square feet)				Natural Gas Energy Intensity (cubic feet/square foot)			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
All Buildings*	415	683	460	311	9,181	13,163	13,311	7,813	45.2	51.9	34.6	39.8
Building Floorspace (Square Feet)												
1,001 to 5,000	46	91	65	40	513	1,074	869	628	90.4	84.9	74.9	63.7
5,001 to 10,000	38	57	64	44	621	959	1,349	763	61.3	59.0	47.5	57.2
10,001 to 25,000	51	119	70	60	1,173	2,436	2,066	1,378	43.9	48.7	33.8	43.6
25,001 to 50,000	45	115	47	44	977	2,262	1,589	1,196	45.6	50.7	29.4	36.6
50,001 to 100,000	58	94	59	25	1,645	1,930	2,153	955	35.5	48.7	27.3	26.3
100,001 to 200,000	65	86	67	24	1,706	1,777	2,241	921	38.3	48.4	29.7	25.6
200,001 to 500,000	60	71	41	28	1,588	1,673	1,419	999	37.6	42.3	28.6	27.5
Over 500,000	51	51	49	Q	956	1,052	1,625	973	53.4	48.8	30.0	48.3
Principal Building Activity												
Education	51	113	47	48	1,347	2,184	2,291	1,222	38.2	51.8	20.6	39.6
Food Sales	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Food Service	Q	50	87	Q	Q	379	623	Q	Q	133.2	139.3	Q
Health Care	47	64	87	38	464	657	987	436	100.9	97.0	88.4	86.1
Inpatient	41	50	80	27	351	395	812	247	117.4	127.2	98.6	108.1
Outpatient	Q	14	Q	Q	Q	262	Q	Q	Q	51.5	Q	Q
Lodging	35	66	55	52	982	1,015	1,338	920	Q	65.0	41.1	56.6
Retail (Other Than Mall)	16	37	23	12	385	688	1,148	645	42.3	54.1	20.4	18.3
Office	89	104	33	35	2,301	2,447	1,915	1,544	38.8	42.3	17.2	23.0
Public Assembly	16	43	22	18	712	770	699	542	Q	56.4	32.1	32.4
Public Order and Safety	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Religious Worship	15	37	20	8	384	899	923	424	38.4	41.4	21.7	18.1
Service	23	57	28	Q	368	934	822	Q	62.2	61.3	34.6	Q
Warehouse and Storage	25	61	20	Q	985	1,921	1,617	971	25.8	31.9	12.1	Q
Other	45	Q	Q	Q	531	Q	Q	Q	85.5	Q	Q	Q
Vacant	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Year Constructed												
Before 1920	42	66	Q	Q	950	1,175	Q	Q	43.8	56.4	Q	Q
1920 to 1945	88	94	23	18	1,845	1,344	790	699	47.9	69.6	28.8	25.7
1946 to 1959	56	85	46	24	1,406	1,681	953	620	39.5	50.5	48.1	38.3
1960 to 1969	58	94	50	46	1,276	1,819	1,428	1,113	45.4	51.8	35.1	40.9
1970 to 1979	55	138	74	74	1,162	2,737	2,265	1,494	47.6	50.4	32.5	49.4
1980 to 1989	40	77	89	75	1,016	1,342	2,520	1,592	39.6	57.7	35.5	47.4
1990 to 1999	44	94	121	46	949	2,126	3,708	1,395	46.2	44.1	32.6	33.0
2000 to 2003	32	35	39	16	576	939	1,261	654	56.3	37.6	31.3	23.8
Climate Zone: 30-Year Average												
Under 2,000 CDD and --												
More than 7,000 HDD	Q	235	N	122	Q	4,382	N	2,102	53.3	53.6	N	57.9
5,500-7,000 HDD	188	405	N	66	3,692	7,947	N	1,211	51.0	51.0	N	54.1
4,000-5,499 HDD	165	44	104	14	4,328	834	2,508	443	38.1	52.3	41.5	30.8
Fewer than 4,000 HDD	N	N	249	99	N	N	6,748	3,761	N	N	36.8	26.2
2,000 CDD or More and --												
Fewer than 4,000 HDD	N	N	107	11	N	N	4,054	296	N	N	26.5	37.9

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, C, and E of the 2003 Commercial Buildings Energy Consumption Survey. http://www.eia.doe.gov/emeu/cbecs

Table US1. Total Energy Consumption, Expenditures, and Intensities, 2005
Part 1: Housing Unit Characteristics and Energy Usage Indicators

Housing Unit Characteristics and Energy Usage Indicators	U.S. Households (millions)	Number of Members per Household	Floorspace per Household (Square Feet)	Energy Consumption[2]			
				Total U.S. (quadrillion Btu)	Per Household (million Btu)	Per Household Member (million Btu)	Per Square Foot (thousand Btu)
Total	111.1	2.57	2,171	10.55	94.9	37.0	43.7
Census Region and Division							
Northeast	20.6	2.56	2,334	2.52	122.2	47.7	52.4
New England	5.5	2.34	2,472	0.71	129.3	55.3	52.3
Middle Atlantic	15.1	2.64	2,284	1.81	119.7	45.3	52.4
Midwest	25.6	2.47	2,421	2.91	113.5	46.0	46.9
East North Central	17.7	2.49	2,483	2.09	117.7	47.3	47.4
West North Central	7.9	2.43	2,281	0.82	104.1	42.9	45.7
South	40.7	2.52	2,161	3.25	79.8	31.6	37.0
South Atlantic	21.7	2.50	2,243	1.65	76.1	30.4	33.9
East South Central	6.9	2.42	2,137	0.60	87.3	36.1	40.9
West South Central	12.1	2.62	2,028	1.00	82.4	31.4	40.6
West	24.2	2.76	1,784	1.87	77.4	28.1	43.4
Mountain	7.6	2.67	1,951	0.68	89.8	33.7	46.0
Pacific	16.6	2.80	1,708	1.19	71.8	25.7	42.0
Four Most Populated States							
New York	7.1	2.72	1,961	0.84	118.2	43.5	60.3
Florida	7.0	2.51	1,869	0.42	60.0	23.9	32.1
Texas	8.0	2.76	2,168	0.65	81.5	29.5	37.6
California	12.1	2.75	1,607	0.81	67.1	24.4	41.7
All Other States	76.9	2.51	2,307	7.82	101.8	40.5	44.1
Urban/Rural Location (as Self-Reported)							
City	47.1	2.53	1,781	4.02	85.3	33.7	47.9
Town	19.0	2.58	2,167	1.94	102.3	39.7	47.2
Suburbs	22.7	2.70	2,688	2.46	108.6	40.3	40.4
Rural	22.3	2.52	2,472	2.13	95.1	37.8	38.5
Climate Zone[1]							
Less than 2,000 CDD and--							
Greater than 7,000 HDD	10.9	2.49	2,534	1.29	117.9	47.4	46.5
5,500 to 7,000 HDD	26.1	2.50	2,346	3.00	115.0	45.9	49.0
4,000 to 5,499 HDD	27.3	2.60	2,205	2.78	101.7	39.1	46.1
Fewer than 4,000 HDD	24.0	2.61	1,966	1.83	76.4	29.2	38.8
2000 CDD or More and--							
Less than 4,000 HDD	22.8	2.60	1,971	1.65	72.4	27.9	36.7
Type of Housing Unit and Number of Bedrooms							
Single-Family Homes							
Detached	72.1	2.73	2,720	7.81	108.4	39.7	39.8
Less than 3 Bedrooms	12.3	2.06	1,917	1.09	89.0	43.3	46.4
3 Bedrooms	38.8	2.65	2,568	3.91	100.9	38.1	39.3
4 Bedrooms	17.1	3.14	3,370	2.18	127.5	40.6	37.8
5 or More Bedrooms	3.9	3.81	3,920	0.62	160.2	42.1	40.9
Attached	7.6	2.48	1,941	0.68	89.3	36.1	46.0
Less than 3 Bedrooms	3.5	2.03	1,414	0.26	74.1	36.5	52.4
3 Bedrooms	3.2	2.67	2,124	0.31	96.3	36.1	45.3
4 or More Bedrooms	0.9	3.53	3,307	0.11	123.1	34.9	37.2
Apartments in							
2 to 4 Unit Buildings	7.8	2.42	1,090	0.66	85.0	35.1	78.0
Less than 2 Bedrooms	2.0	1.71	809	0.16	79.1	46.3	97.8
2 Bedrooms	4.3	2.45	1,092	0.32	74.7	30.5	68.4
3 or More Bedrooms	1.5	3.29	1,459	0.18	123.0	37.4	84.3
5 or More Unit Buildings	16.7	2.04	872	0.91	54.4	26.7	62.4
Less than 2 Bedrooms	7.9	1.47	672	0.37	46.4	31.7	69.0

2 Bedrooms	7.4	2.34	978	0.45	60.7	25.9	62.1
3 or More Bedrooms	1.4	3.64	1,425	0.09	66.2	18.2	46.5
Mobile Homes	6.9	2.47	1,059	0.49	70.4	28.5	66.5
Less than 3 Bedrooms	3.5	2.05	838	0.22	63.0	30.8	75.2
3 or More Bedrooms	3.5	2.89	1,279	0.27	77.8	26.9	60.8
Ownership of Housing Unit							
Owned	78.1	2.59	2,586	8.16	104.4	40.3	40.4
Single-Family Detached	64.1	2.67	2,813	7.04	109.8	41.1	39.1
Single-Family Attached	4.2	2.36	2,400	0.40	94.9	40.2	39.5
Apartments in 2-4 Unit Buildings	1.8	2.23	1,604	0.20	110.5	49.5	68.9
Apartments in 5 or more Unit Buildings	2.3	1.65	1,116	0.12	50.9	30.8	45.6
Mobile Homes	5.7	2.39	1,099	0.40	70.5	29.5	64.1
Rented	33.0	2.51	1,188	2.39	72.4	28.9	61.0
Single-Family Detached	8.0	3.17	1,983	0.77	96.5	30.5	48.7
Single-Family Attached	3.4	2.62	1,383	0.28	82.6	31.5	59.7
Apartments in 2-4 Unit Buildings	5.9	2.48	930	0.46	77.1	31.1	82.9
Apartments in 5 or more Unit Buildings	14.4	2.10	833	0.79	55.0	26.2	66.0
Mobile Homes	1.2	2.84	866	0.08	70.0	24.6	80.8
Year of Construction							
Before 1940	14.7	2.46	2,325	1.77	120.4	48.9	51.8
1940 to 1949	7.4	2.44	2,047	0.77	104.0	42.7	50.8
1950 to 1959	12.5	2.43	2,052	1.23	98.3	40.5	47.9
1960 to 1969	12.5	2.64	1,969	1.18	94.9	35.9	48.2
1970 to 1979	18.9	2.49	1,863	1.58	83.4	33.5	44.8
1980 to 1989	18.6	2.52	1,992	1.51	81.4	32.3	40.9
1990 to 1999	17.3	2.80	2,501	1.64	94.4	33.7	37.7
2000 to 2005	9.2	2.76	2,827	0.87	94.4	34.2	33.4
Total Floorspace (Square Feet)							
Fewer than 500	3.2	1.90	375	0.18	56.5	29.8	150.8
500 to 999	23.8	2.14	765	1.48	62.0	29.0	81.1
1,000 to 1,499	20.8	2.66	1,235	1.71	82.0	30.9	66.4
1,500 to 1,999	15.4	2.67	1,745	1.45	93.8	35.1	53.8
2,000 to 2,499	12.2	2.68	2,233	1.25	102.3	38.2	45.8
2,500 to 2,999	10.3	2.69	2,735	1.16	112.2	41.7	41.0
3,000 to 3,499	6.7	2.57	3,239	0.78	115.6	45.0	35.7
3,500 to 3,999	5.2	2.64	3,742	0.68	129.2	48.9	34.5
4,000 or More	13.3	3.02	5,421	1.87	140.4	46.5	25.9
Weekday Home Activities							
Home Used for Business							
Yes	8.9	2.81	2,904	1.04	117.2	41.8	40.4
No	102.2	2.55	2,107	9.50	93.0	36.5	44.1
Energy-Intensive Activity							
Yes	2.2	2.82	2,437	0.25	110.9	39.4	45.5
No	108.9	2.56	2,165	10.30	94.6	36.9	43.7
Someone Home All Day							
Yes	56.4	2.72	2,207	5.59	99.2	36.4	45.0
No	54.7	2.41	2,134	4.95	90.5	37.6	42.4

1 One of five climatically distinct areas, determined according to the 30-year average (1971-2000) of the annual heating and cooling degree-days. to the 30-year average annual degree-days for an appropriate nearby weather station.

2 Energy consumption and expenditures in this table excludes primary electricity and wood.

Q = Data withheld either because the Relative Standard Error (RSE) was greater than 50 percent or fewer than 10 households were sampled.

N = No cases in the reporting sample.

(*) Number less than 0.5, 0.05, or 0.005 depending on the number of significant digits in the column, rounded to zero.

Notes: • Because of rounding, data may not sum to totals. • See "Glossary" for definition of terms used in this report.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-457 A-G of the 2005 Residential Energy Consumptic

Source:

http://www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html

INDUSTRIAL SOURCE SCREEN FOR POTENTIAL CUMULATIVE IMPACTS

Section 322.1 in Chapter 17, "Air Quality," outlines the methodology for analysis of an additional screen for industrial sources from a single point pollutant source. This appendix describes how to determine potential cumulative impact from multiple sources. Table 17-3 depicts maximum concentration values for various time periods (1-hour, 8-hour, 24-hour and annual) for the distances from 10 meters to 120 meters (33 feet to 394 feet) and the shortest stack and receptor height (10 meters). This table is based on the generic emission rate of 1 gram per second of pollutant from a point source and the latest five years of available meteorological data (2003-2007) from La Guardia airport. Default values from the CEQR manual were used: stack exit velocity employed was 0.001 m/s, stack diameter was assumed to be 0 meters and stack exit temperature was set at 293K. Step-by-step methodology outlined below explains how to accurately use the values in this table to determine the potential cumulative impact from industrial emissions on a new proposed project:

1. Identify all sources with potential impact on the proposed project.
2. Convert the estimated emissions of each pollutant from the industrial sources of concern into grams/second.
3. Determine distance to each point pollution source.
4. Using the look up table, find the corresponding concentration for distance between each industrial source and the new use of concern for desired averaging time.
5. For each point, multiply the emission rates from step 2 with the value from the table (step 4).
6. Combine these values to determine potential cumulative impact.

Table 17-3
Industrial Source Screen

20 Foot Source Height

Distance from Source	1-Hour Averaging Period (ug/m3)	8-Hour Averaging Period (ug/m3)	24-Hour Averaging Period (ug/m3)	Annual Averaging Period (ug/m3)
30 ft	137,169	70,848	40,031	6,020
65 ft	29,719	16,528	9,194	1,336
100 ft	12,729	7,561	4,151	583
130 ft	7,689	4,764	2,590	356
165 ft	4,865	3,136	1,688	228
200 ft	3,370	2,252	1,201	159
230 ft	2,622	1,779	942	123
265 ft	2,113	1,402	736	95
300 ft	1,754	1,144	595	76
330 ft	1,520	978	505	64
365 ft	1,308	832	426	54
400 ft	1,144	720	365	46

http://www.epa.gov/ttn/chief/AP42/ch01/final/c01s03.pdf

AP-42

Table 1.3-1. (cont.)

Firing Configuration (SCC)[a]	SO_2[b] Emission Factor (lb/10³ gal)	SO_2[b] EMISSION FACTOR RATING	SO_3[c] Emission Factor (lb/10³ gal)	SO_3[c] EMISSION FACTOR RATING	NO_x[d] Emission Factor (lb/10³ gal)	NO_x[d] EMISSION FACTOR RATING	CO[e] Emission Factor (lb/10³ gal)	CO[e] EMISSION FACTOR RATING	Filterable PM[f] Emission Factor (lb/10³ gal)	Filterable PM[f] EMISSION FACTOR RATING
Boilers < 100 Million Btu/hr										
No. 6 oil fired (1-02-004-02/03) (1-03-004-02/03)	157S	A	2S	A	55	A	5	A	10	B
No. 5 oil fired (1-03-004-04)	157S	A	2S	A	55	A	5	A	9.19(S)+3.22	A
No. 4 oil fired (1-03-005-04)	150S	A	2S	A	20	A	5	A	7	B
Distillate oil fired (1-02-005-02/03) (1-03-005-02/03)	142S	A	2S	A	20	A	5	A	2	A
Residential furnace (A2104004/A2104011)	142S	A	2S	A	18	A	5	A	0.4[g]	B

[a] To convert from lb/10³ gal to kg/10³ L, multiply by 0.120. SCC = Source Classification Code.

[b] References 1-2,6-9,14,56-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.

[c] References 1-2,6-8,16,57-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.

[d] References 6-7,15,19,22,56-62. Expressed as NO_2. Test results indicate that at least 95% by weight of NO_x is NO for all boiler types except residential furnaces, where about 75% is NO. For utility vertical fired boilers use 105 lb/10³ gal at full load and normal (>15%) excess air. Nitrogen oxides emissions from residual oil combustion in industrial and commercial boilers are related to fuel nitrogen content, estimated by the following empirical relationship: lb NO_2/10³ gal = 20.54 + 104.39(N), where N is the weight % of nitrogen in the oil. For example, if the fuel is 1% nitrogen, then N = 1.

[e] References 6-8,14,17-19,56-61. CO emissions may increase by factors of 10 to 100 if the unit is improperly operated or not well maintained.

[f] References 6-8,10,13-15,56-60,62-63. Filterable PM is that particulate collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. Particulate emission factors for residual oil combustion are, on average, a function of fuel oil sulfur content where S is the weight % of sulfur in oil. For example, if fuel oil is 1% sulfur, then S = 1.

[g] Based on data from new burner designs. Pre-1970's burner designs may emit filterable PM as high as 3.0 lb/10³ gal.

S = .2

$142 \times 0.2 = 28.4$ lb/10³ gal = 0.0284 lbs/gallon

Fuel Consumption 1993
Residential

	sq ft million	Total Btu (tril)	Btu/sq ft (thousand)	Electricity	minus Elec (tril Btu)	heating Btu/sq ft (thou)	cubic ft/sq ft NG	gallons/sq ft #2 fuel oil	gallons/sq ft #4 & 6 fuel oil
average	181200	9966	55.0	3280	6686	36.9	36.2	0.26	0.25
Year Constructed									
before 1939	40600	2639	65.0	510	2129	52.4	51.4	0.37	0.35
1940-1949	11600	777.2	67.0	200	577.2	49.8	48.8	0.36	0.33
1950-1959	24700	1482	60.0	420	1062	43.0	42.2	0.31	0.29
1960-1969	27200	1550.4	57.0	490	1060.4	39.0	38.2	0.28	0.26
1970-1979	31700	1585	50.0	710	875	27.6	27.1	0.20	0.18
1980-1984	14700	676.2	46.0	350	326.2	22.2	21.8	0.16	0.15
1985-1987	10800	475.2	44.0	230	245.2	22.7	22.3	0.16	0.15
1988-1990	10000	430	43.0	210	220	22.0	21.6	0.16	0.15
1991-1993	10000	400	40.0	160	240	24.0	23.5	0.17	0.16
Northeast	40100	2406	60	470	1936	48.3	47.3	0.34	0.32
New York	12800.0	819.2	64.0	130	689.2	53.8	52.8	0.38	0.36
Type of Housing Unit									
Single Family	152200	7914.4	52	2580	5334.4	35.0	34.4	0.25	0.23
Detached	139100	7233.2	52	2340	4893.2	35.2	34.5	0.25	0.23
Attached	13100	694.3	53	240	454.3	34.7	34.0	0.25	0.23
Mobile Home	5400	453.6	84	210	243.6	45.1	44.2	0.32	0.30
Multifamily	23600	1628.4	69	490	1138.4	48.2	47.3	0.34	0.32
2 -4 units	9600	796.8	83	170	626.8	65.3	64.0	0.47	0.44
5 or more units	14000	840	60	320	520	37.1	36.4	0.27	0.25

Fuel Consumption - 1995
Commercial Use

	sq ft (million)	Total Btu (tril)	Btu/sq ft (thousand)	Electricity	minus Elec (tril Btu)	heating Btu/sq ft (thou)	cubic ft/sq ft NG	gallons/sq ft #2 fuel oil	gallons/sq ft #4 & 6 fuel oil
average	58772	5321	90.5	2608	2713	46.2	45.3	0.33	0.31
Year Constructed									
before 1919									
1900-1919	3673	292	79.5	99	193	52.5	51.5	0.38	0.35
1920-1945	6710	508	75.7	173	335	49.9	48.9	0.36	0.33
1946-1959	9298	826	88.8	325	501	53.9	52.8	0.38	0.36
1960-1969	10858	1024	94.3	472	552	50.8	49.8	0.36	0.34
1970-1979	11333	1125	99.3	615	510	45.0	44.1	0.32	0.30
1980-1989	12252	1059	86.4	648	411	33.5	32.9	0.24	0.22
1990-1992	2590	297	114.7	163	134	51.7	50.7	0.37	0.34
1993-1995	2059	190	92.3	113	77	37.4	36.7	0.27	0.25
size (sq. ft)									
1001-5000	6338.0	708	111.7	380	328	51.8	50.7	0.37	0.35
5001-10000	7530.0	624	82.9	238	386	51.3	50.3	0.37	0.34
10001-25000	11617.0	824	70.9	384	440	37.9	37.1	0.27	0.25
25001-50000	7676.0	630	82.1	316	314	40.9	40.1	0.29	0.27
50001-100000	7968.0	698	87.6	363	335	42.0	41.2	0.30	0.28
100001-200000	6776.0	687	101.4	337	350	51.7	50.6	0.37	0.34
200001-500000	5553.0	636	114.5	307	329	59.2	58.1	0.42	0.39
over 500000	5313.0	514	96.7	282	232	43.7	42.8	0.31	0.29
Northeast	11883.0	1035	87.1	436	599	50.4	49.4	0.36	0.34