APPENDIX G

Revised SIP Modeling Procedures for the HGA Nonattainment Area

Houston/Galveston Attainment Demonstration and
Post-1999 Rate-of-Progress SIP

December 2000

MEMORANDUM

Eastern Research Group, Inc.
5608 Parkcrest Drive, Suite 100
Austin, TX 78731-4947

Date: July 26, 2000
To: Hazel Barbour (TNRCC)
From: Rick Baker (ERG)
Cc: Distribution
Re: **Revised SIP Modeling Procedures for Houston Ozone Non-Attainment Areas**

INTRODUCTION

This memo summarizes the assumptions and methods used by ERG to estimate NOx emission reductions for the various on-road control measures under consideration by the TNRCC for the upcoming SIP submissions for the Houston area. All calculations are for the year 2007, for the 8 county ozone non-attainment area. In addition, the 8 county area is broken into three regions for reporting purposes – Harris county, urban counties, and rural counties.[1] All controls were evaluated in a sequential, incremental fashion, and all ton per day values reported below are additive. These calculations were performed in order to establish a consistent, uniform basis for estimating SIP credits for the Houston area.

Several inconsistencies were identified in the previous on-road SIP calculations, and have been addressed herein. The on-road inventory adjustments and emission reduction measures addressed by ERG include:

- MOBILE5ah adjustment
- Adjustment for Appropriate ("Max") I/M in Harris County
- Vehicle registration adjustment using 1999 TxDOT data
- Tier 2 / Low-Sulfur Rule Adjustment
- Enhanced I/M program reduction
- Low Emission Diesel rule reduction
- 15 ppm gasoline rule reduction
- Heavy-duty vehicle idle rule reduction
- Diesel emulsion rule reduction
- NOx catalyst rule reduction

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[1] Urban counties include Brazoria, Ft. Bend, Galveston, and Montgomery. Rural counties include Chambers, Liberty, and Waller.

The following summarizes the methodology and assumptions used to estimate these adjustments and emission reduction estimates.

Future Baseline

ERG obtained the COAST study data from TNRCC staff as the starting point for the analysis. The COAST data obtained, as developed by TTI, contains projected VMT and emissions for 2007, by county, vehicle class, and road type, for the Wednesday modeling episode. This is the same VMT data used by the SIP Planning Section at the TNRCC for preparation of the gridded inventories for photochemical modeling. In consultation with TNRCC staff, ERG elected to use the VMT and VMT mix data from this data for all subsequent emission reduction calculations. Table 1 summarizes the VMT and NOx ton per day values from the COAST data set.

Table 1
2007 Future Base On-Road VMT and NOx Inventory, by Region and Vehicle Class

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
VMT (Miles per Day)									
Harris	71,017,884	15,850,052	4,589,402	3,216,125	304,655	101,551	6,370,605	101,551	1.02E+08
Urban	22,276,575	5,224,083	1,507,912	1,010,974	96,556	32,185	2,005,154	32,185	32,185,625
Rural	3,993,280	906,190	262,142	181,115	17,190	5,730	358,949	5,730	5,730,330
Total	**97,287,739**	**21,980,326**	**6,359,457**	**4,408,214**	**418,403**	**139,467**	**8,734,709**	**139,467**	**1.39E+08**
VMT Mix									
Harris	0.699	0.156	0.045	0.032	0.003	0.001	0.063	0.001	1.000
Urban	0.692	0.162	0.047	0.031	0.003	0.001	0.062	0.001	1.000
Rural	0.697	0.158	0.046	0.032	0.003	0.001	0.063	0.001	1.000
NOx Emissions (Tons per Day)									
Harris	87.72	21.88	10.58	15.40	0.39	0.15	54.38	0.12	190.62
Urban	37.80	9.67	3.41	5.51	0.13	0.05	19.88	0.04	76.49
Rural	7.47	1.87	0.66	1.04	0.03	0.01	4.11	0.01	15.20
Total	**132.99**	**33.43**	**14.65**	**21.96**	**0.55**	**0.20**	**78.36**	**0.18**	**282.32**

MOBILE5ah Adjustment

TTI used MOBILE5ah to develop their future base inventory (see above). However, ERG has consistently used MOBILE5b for all of its emission reduction modeling.[2] Therefore ERG ran MOBILE5ah and MOBILE5b under identical conditions for each area to develop conversion factors. These factors are used to "map" emissions estimates generated using MOBILE5ah to an equivalent MOBILE5b value. Table 2 summarizes the resulting MOBILE5ah adjustments in tons per day.

[2] MOBILE5b was needed to generate by model year emission factor outputs under summer conditions for model-year dependent programs – an option not available in MOBILE5ah. In addition, NOx RFG correction factors are not needed when modeling with MOBILE5b, simplifying subsequent calculations.

Table 2
MOBILE5ah to MOBILE5b Adjustments

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
Adjustment Factors									
Harris	0.975	0.983	0.976	0.982	1.000	1.000	1.000	0.981	
Urban	0.984	0.985	0.975	0.980	1.000	1.000	1.000	0.981	
Rural	0.979	0.986	0.972	0.979	1.000	1.000	1.000	0.981	
NOx Reductions (Tons per Day)									
Harris	2.23	0.37	0.25	0.28	0.00	0.00	0.00	0.00	3.14
Urban	0.59	0.14	0.09	0.11	0.00	0.00	0.00	0.00	0.93
Rural	0.16	0.03	0.02	0.02	0.00	0.00	0.00	0.00	0.22
Total	**2.98**	**0.54**	**0.36**	**0.41**	**0.00**	**0.00**	**0.00**	**0.00**	**4.29**

The resulting adjustment factors lower emission estimates from about 1 to 3 percent. The overall adjustment lowers the total on-road inventory by 4.29 tons per day.

Appropriate (Max) I/M Adjustment

The TTI MOBILE5ah input files used to generate the COAST ton per day projections activated the "Max I/M" flag in the LEV parameter record for their Harris County runs. Under Max I/M it is assumed that all vehicles meeting LEV or better emission standards will emit no more than 1.5 times the emission certification level, regardless of mileage or age. This results in extremely low emission rates for 2001 and later model years.

EPA has subsequently stated that Max I/M is not a reasonable program under real-world conditions, and should not be used for modeling purposes. Therefore ERG estimated the benefit attributable to Max I/M as modeled by TTI, and removed this benefit from the inventory. Table 3 summarizes the effect of this adjustment. Note that this program was not modeled for the urban and rural counties, so no adjustment is necessary for these other regions.

Table 3
Max I/M NOx Adjustments for Harris County

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
Harris	-18.51	-4.00	0.00	0.00	0.00	0.00	0.00	0.00	-22.51

The negative values above indicate that the adjustments actually increase the inventory values.

Registration Adjustment

The COAST data set relied upon old vehicle registration distributions (circa 1993) to develop the future base inventory. ERG obtained 1999 calendar year registration mixes for each region from TxDOT, and determined the difference in MOBILE5b outputs using the new and old registration data to develop adjustment factors. Talbe4 summarizes the resulting ton per day impacts. Appendix 1 provides a listing of the COAST and 1999 registration distributions used in this analysis.

Table 4
Registration Adjustments Using 1999 TxDOT Data

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
Adjustment Factors									
Harris	0.99	0.95	0.73	1.04	1.00	0.99	0.90	1.00	0.95
Urban	1.03	0.98	0.64	1.10	1.01	0.99	0.94	1.00	0.98
Rural	1.03	0.99	0.60	1.05	1.01	1.01	0.87	1.00	0.96
NOx Reductions (Tons per Day)									
Harris	0.95	1.31	2.82	-0.54	0.00	0.00	5.26	0.00	9.80
Urban	-0.98	0.22	1.21	-0.53	0.00	0.00	1.11	0.00	1.04
Rural	-0.23	0.03	0.27	-0.05	0.00	0.00	0.53	0.00	0.54
Total	**-0.26**	**1.56**	**4.31**	**-1.12**	**0.00**	**0.00**	**6.90**	**0.00**	**11.38**

As seen in the Table, by far the largest change in emissions projections results from the LDT2 category. The latest registration data clearly indicate that there has been a surge in new truck sales in this category in the last few years, resulting in a much newer LDT2 fleet. The net effect is to lower the future base inventory by 11.38 tpd. This estimate is relatively close to the 13.65 tpd estimate independently provided by the Harris County Tax Assessor's Office.

Tier 2 / Low-Sulfur Adjustment

In consultation with EPA OTAQ and Region 6, the local Councils of Governments, and representatives of the auto manufacturers, TNRCC and ERG recalculated the emissions levels in tons per day, for VOC and NOx, in 2007 and subsequent years, for EPA's Tier 2 rule. The analysis evaluated both light-duty vehicles (up to 8,500 lbs. Gross Vehicle Weight (gvw)), and the heavy-duty component of the Tier 2 and LEV programs (8,500 – 14,000 gvw).

In order to reflect EPA's latest information from their Tier 2 model, ERG worked with OTAQ staff to develop adjustment factors to apply to the outputs of the MOBILE5b model for each area and target year. (While EPA had previously used the Tier 2 model to estimate emissions benefits for the Houston region, these estimates did not include locality-specific inputs such as vehicle age distributions.)

MOBILE5b outputs were then combined with EPA's Tier 2 adjustment factors to estimate new exhaust emission factors. Finally, adjusted emission factors were combined with the COAST VMT and VMT mix data to estimate emissions in tons per day.[3] The VMT mix data was based on past data (1993). To reflect the recent trend away from passenger cars toward heavier trucks, EPA suggested that ERG use projections of future year VMT mixes from the upcoming MOBILE6 model to adjust the local data. This adjustment tended to increase the absolute ton per day emissions.

Table 5 summarizes the benefits of the upcoming national Tier 2 / Low Sulfur rule.

[3] Note that the original Tier 2 analysis performed in conjunction with EPA OTAQ did not use the COAST VMT and VMT mix data. Using the COAST data in the previous analysis increases the Tier 2 benefit estimates from 30.66 tpd to 31.63 tpd.

Table 5
Incremental Adjustment Factors for Tier 2 / Low-Sulfur Rule

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Harris	14.71	6.75	1.67	0	0	0	0	0	23.13
Urban	4.51	2.22	0.48	0	0	0	0	0	7.21
Rural	0.86	0.37	0.07	0	0	0	0	0	1.29
Total	**20.07**	**9.34**	**2.22**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**31.63**

Enhanced Inspection and Maintenance (I/M)
ERG modeled the emission benefits associated with 8 county adoption of a combined ASM/OBD program. The proposed program start dates for each region are:

- Harris County – 2002
- Urban Counties -- 2003
- Rural Counties -- 2004

Adoption of OBD II checks is universally assumed for all areas with an operating I/M program. These checks would be performed annually in place of the 2-speed idle test for all 1996 and later vehicles. To model the effects of OBD II, ERG assumed an effectiveness equivalent to an annual IM240 program with full cutpoints. This assumption is consistent with EPA's preliminary findings from its ongoing OBD II test program. (Ed Gardetto, "Preliminary Analysis of On-Board Diagnostics for Use in I/M", presentation in Snowmass Colorado, September 17, 1999.)[4]
(Note that those areas with the oldest fleets, in relative terms, tend to obtain the least benefit from this measure -- e.g., the rural HGA fleet).

Acceleration Simulation Mode (ASM) testing provides an alternative means of performing loaded mode testing in an I/M program. ERG estimated the emission reductions assuming annual ASM (5015/2525) with phase-in cutpoints for pre-1996 vehicles previously subject to the TMC.

Table 6 summarizes the NOx benefits expected from a combined ASM/OBD program with the above start dates, relative to the current I/M baseline (two-speed idle in Harris County, no I/M in the remaining counties.) Appendix 2 provides the MOBILE5b input files used to develop these estimates.

[4] In fact, preliminary indications are that OBD II checks may actually perform better than IM240 in the field. ERG assumed equivalency of the programs to be conservative.

Table 6
NOx Reductions from Enhanced I/M

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Harris	21.07	3.93	1.10	0.00	0	0	0	0	26.10
Urban	10.47	2.27	0.41	0.09	0	0	0	0	13.24
Rural	2.16	0.44	0.07	0.01	0	0	0	0	2.69
Total	**33.71**	**6.65**	**1.57**	**0.10**	**0.00**	**0.00**	**0.00**	**0.00**	**42.03**

Texas Low Emission Diesel (LED) Rule

Texas LED fuel benefits were evaluated relative to industry average on-road diesel fuel (as provided in EPA's HDEWG report). The assumed fuel properties for this analysis were as follows:

	Federal On-Road	LED ^
Density (kg/m3)	845	830*
Mono-aromatics (%m)	25	17.9**
Poly-aromatics (%m)	9	2.1
Cetane #	45	50
T95 (C)	330^^	330^^
Sulfur (ppm)	350	50

^ Assumed to equal Cal Diesel parameters, from 1996 ARB survey of in-use fuel.
* Assumed, as a counter-effect to alternative reformulation
**Alternative reformulation required with >10% total aromatics
^^ Extrapolated from HDEWG graphs.

We compared the regression equations generated under the HDEWG study with those from the European Auto Oil study. Given similar inputs these models tend to agree in their NOx predictions, with < 2.0% difference. Selecting the HDEWG model, NOx reductions are predicted to be 5.7% for on-road engines with electronic controls (i.e., 1990 and later models for the most part). Note that the European Auto Oil equations estimated a 4.1% NOx reduction for the same engines.

Also note that pre-1990 engine benefits were estimated using ARB test data from 1988. While this data set is thin, it is the only data available for estimating aromatics effects in pre-electronic control engines (estimated at 7% for NOx). Therefore we relied on this estimate for the older portion of the on-road fleet, as well as the entire off-road diesel fleet. Weighting these reductions by the appropriate model year and fuel type fractions yields the following overall adjustment factors for the on-road fleet.

Fleet average impacts were determined by estimating the fraction of total NOx emissions attributable to pre-1990 HDD engines for each region. Approximately 3 percent of on-road emissions come from these engines, according to the by-model-year outputs from MOBILE5b. Weighting total emissions accordingly by the 5.7 and 7% reductions noted above, Table 7 summarizes the benefits for the Texas LED Rule in the 8 county area, assuming 100% rule effectiveness. (Note this calculation does not account for VMT from trucks using fuel purchased outside of the LED Rule area.)

Table 7
Incremental Adjustment Factors for the Texas LED Rule

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Harris	0	0	0	0	0.02	0.01	2.82	0	2.85
Urban	0	0	0	0	0.01	0.00	1.08	0	1.09
Rural	0	0	0	0	0.00	0.00	0.21	0	0.21
Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.01**	**4.10**	**0.00**	**4.15**

15 ppm Gasoline

Ideally, NOx benefit estimates for 15 ppm sulfur gasoline would be based on actual emissions test data using a variety of vehicles operating on such a fuel. However ERG has not been able to identify any emissions test data using gasoline with sulfur levels lower than 30 ppm. Therefore projecting emissions benefits for this measure using models based on existing data are inherently uncertain.

ERG first investigated using the sulfur correction functions in EPA's Tier 2 spreadsheet model to estimate the benefits of ultra-low sulfur gasoline. However, the curve fitting procedure used by EPA assumed a complicated exponential relationship between sulfur levels and NOx emissions. As a result, NOx emissions are predicted to fall off drastically at sulfur levels just below 30 ppm. In fact, emissions approach 0 for certain vehicle classes as sulfur levels go to 0. ERG believes that this is actually an artifact of the modeling process, rather than a real response. If used, these functions are likely to significantly overestimate the NOx benefits for gasolines below 30 ppm.

For these reasons ERG chose to use EPA's Complex Model to estimate NOx benefits for this measure. Although the Complex Model does not utilize data from gasolines below 30 ppm sulfur either, the model predicts a more linear response than the Tier 2 model. Therefore ERG believes the Complex Model provides a more realistic basis for estimating NOx benefits for gasolines below 30 ppm than does the Tier 2 model.

The Complex Model is a generalized tool for evaluating fuel effects at the national level, and it cannot account for fleet-specific differences such as vehicle age distributions. Therefore ERG assumed the NOx benefits derived from the model could be applied equally to all Houston area fleets. The baseline fuel parameters used in the model are summarized below.

Table 8 – Baseline Fuel Parameters Used in the Complex Model

Parameter	Reformulated Gasoline
Area Class	B
Phase	2
Season	Summer
% Oxygen	2.1
RVP	6.6
Sulfur	30
Aromatics	24%

Olefins	11%
Benzene	0.80%
E200	52
E300	84

The Reformulated Gasoline profile was obtained from EPA OTAQ staff. These parameters represent EPA's "best guess" as to the components of Federal Phase II RFG, derived for use in their regulatory impact analysis. Sulfur levels are set at the Tier 2 standards. We assume this fuel will be used in the Houston non-attainment counties.

Next ERG varied the Complex Model inputs for each of these fuels, lowering sulfur levels from 30 to 15 ppm. The resulting correction factor is 0.992. Table 9 summarizes the resulting emissions reductions for this measure, assuming 100% rule effectiveness. Again, we did not attempt to quantify the diminished benefit attributable to VMT from vehicles purchasing gasoline outside of the effected region.

Table 9
Emission Reductions from 15 ppm Sulfur Rule

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Harris	0.54	0.11	0.04	0.13	0	0	0	0.00	0.81
Urban	0.19	0.04	0.01	0.05	0	0	0	0.00	0.28
Rural	0.04	0.01	0.00	0.01	0	0	0	0.00	0.05
Total	**0.76**	**0.15**	**0.05**	**0.18**	**0.00**	**0.00**	**0.00**	**0.00**	**1.15**

Heavy-Duty Idle Rule

The benefit calculations for the proposed idle rule are summarized in a separate memo to the TNRCC, "Determination of NOx Benefits from Proposed Idle Shut-Off Rule", dated July 26, 2000. The ton per day benefits are summarized below.

Table 10
Emission Reductions from Heavy-Duty Idle Rule

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Harris	0	0	0	0.003	0	0	0.68	0	0.68
Urban	0	0	0	0	0	0	0.20	0	0.20
Rural	0	0	0	0	0	0	0.03	0	0.03
Total	**0.00**	**0.00**	**0.00**	**0.003**	**0.00**	**0.00**	**0.92**	**0.00**	**0.92**

Diesel Emulsions Rule

At this time there is no data available from the Port of Houston pilot testing of the Lubrizol diesel emulsions package. Therefore ERG relied upon previous estimates of emission reduction potential from the

vendor, consistent with the figures used for the previous November SIP submission. ERG used the following parameters in our calculation of NOx benefits:

- 15% emission reductions
- 50% rule effectiveness
- applicable to HDDVs > 26,000 lbs

50% rule effectiveness was assumed based upon an H-GAC estimate that approximately 50% of total HDDV VMT in the 8 county area was attributable vehicles actually registered in the area.

ERG used data from EPA's Fleet Characterization documentation for MOBILE6 (EPA420-P-99-011, April 1999) to obtain an estimate of total heavy-duty VMT attributable to HDDVs > 26,000 lbs. In addition, ERG obtained Basic Emission Rates by weight class for the HDDV fleet, without defeat devices, in the year 2007 (Development and Use of Heavy-Duty Defeat Device Emission Effects for MOBILE5 AND MOBILE6 (M6.HDE.003, posted 10/27/99, EPA420-P-99-030). ERG combined these BERs with the VMT data to obtain an estimate of the fraction of NOx emissions attributable to HDDVs > 26,000 lbs. (about 69% of total heavy-duty emissions). Table 11 summarizes the benefits calculated for this rule.

Table 11
Emission Reductions from Heavy-Duty Diesel Emulsion Rule

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Harris	0	0	0	0	0	0	2.37	0	2.37
Urban	0	0	0	0	0	0	0.91	0	0.91
Rural	0	0	0	0	0	0	0.17	0	0.17
Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.45**	**0.00**	**3.45**

Catalyst Retrofit Rule – Diesel Engines

At this time there is no data available from the Port of Houston pilot testing of the Seimens SiNOx diesel catalyst retrofit package. Therefore ERG relied upon previous estimates of emission reduction potential from the vendor, consistent with the figures used for the previous November SIP submission. ERG used the following parameters in our calculation of NOx benefits:

- 80% emission reductions
- 50% rule effectiveness
- applicable to 1996 and older engines
- applicable to HDDVs > 26,000 lbs

50% rule effectiveness was assumed based upon an H-GAC estimate that approximately 50% of total HDDV VMT in the 8 county area was attributable vehicles actually registered in the area.

ERG used the by-model-year breakouts from MOBILE5b to determine the fraction of total emissions attributable to engines 1996 and older in 2007 (29.5%). ERG also used data from EPA's Fleet

Characterization documentation for MOBILE6 as before to obtain emissions fractions for vehicles > 26,000 lbs. (Vehicles in this weight class certainly utilize engines greater than the 175 hp cut-off specified by the vendor as necessary for adequate catalyst operating temperatures.) Table 12 summarizes the benefits calculated for this rule.

Table 12
Emission Reductions from Heavy-Duty Diesel Catalyst Rule

Region	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Harris	0	0	0	0	0	0	3.54	0	3.54
Urban	0	0	0	0	0	0	2.04	0	2.04
Rural	0	0	0	0	0	0	0.33	0	0.33
Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**5.90**	**0.00**	**5.90**

Summary

The following provides a summary of the inventory adjustments and emission control benefits for each item discussed above, for the 8 county region as a whole. Overall inventory adjustments decrease the baseline by 24.8 tpd. Control measures total 57.6 tpd.

Table 13
On-Road Inventory Adjustments and Control Benefit Summary

Adjustment/Reduction	LDV	LDT1	LDT2	HDGV	LDDV	LDDT	HDDV	MC	Total
NOx Reductions (Tons per Day)									
Baseline	**132.99**	**33.43**	**14.65**	**21.96**	**0.55**	**0.20**	**78.36**	**0.18**	**282.32**
M5ah Adjustment	2.98	0.54	0.36	0.41	0.00	0.00	0.00	0.00	4.29
Max I/M Adjustment	-18.51	-4.00	0.00	0.00	0.00	0.00	0.00	0.00	-22.51
Registration Adjustment	-0.26	1.56	4.31	-1.12	0.00	0.00	6.90	0.00	11.38
Tier 2 Adjustment	20.07	9.34	2.22	0.00	0.00	0.00	0.00	0.00	31.63
Enhanced I/M Reduction	33.71	6.65	1.57	0.10	0.00	0.00	0.00	0.00	42.03
LED Reduction	0.00	0.00	0.00	0.00	0.03	0.01	4.10	0.00	4.15
15 ppm Gas Reduction	0.76	0.15	0.05	0.18	0.00	0.00	0.00	0.00	1.15
Idle Restriction Reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.91
Diesel Emulsion Reduction	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.00	3.45
NOx Catalyst Reduction	0.00	0.00	0.00	0.00	0.00	0.00	5.90	0.00	5.90
Remaining TPD	**94.25**	**19.20**	**6.15**	**22.38**	**0.52**	**0.19**	**57.10**	**0.17**	**199.95**