Alternative to Supplement #1
TO OUTLINES OF OPINIONS

Amoco Sugar Creek Refinery Cases

By

Stephen E. Petty, P.E., C.I.H.

July 25, 2005

Plaintiffs: Lon Walter's Sugar Creek Plaintiffs

Defendants: BP Corporation North America Inc. and BP Products North America Inc. et.al – Former American Oil Company (AMOCO) Site.

Scope of Work:

This scope of work was to determine Mrs. Ryan's likely benzene exposure while she lived in/near her two homes from 1956 to 1980.

This alternative report supplements the previous supplemental report issued on April 15, 2005. Changes to the exposure estimate include:

- Subtraction of an additional two weeks per year from the exposure estimates for vacation time. This is in addition to the 15% discount factor used in the initial estimates. Further, it was assumed that no exposure occurred during vacation time.
- Replacement of the enhancement factor with data on the benzene content of gasoline vapor, based on the work of Gene Tironi and Douglas G. Hodgkins (1991, Appl. Occup. Environ. Hyg. 6 (10), pgs. 881-884). Data from this reference were averaged for winter and summer conditions, used 1990 benzene in gasoline data and were adjusted for estimated gasoline air concentrations and gasoline benzene composition.
- Correction of the initial estimate for a mathematical error in subtracting work time from time in/near the home (note that this changed the initial exposure by less than 1%).
- Correction of Mrs. Ryan's work time at Sears to 1.3 years. This timeframe was prior to her living at the Evans location and had no impact on the initial, or revised, exposure estimates.
- Adjustment of the standard deviations used in the Monte Carlo simulation.

Introduction:

The Sugar Creek, MO neighborhoods, where the plaintiffs lived, were located primarily to the south of the former American Oil Company (AMOCO) refinery. This refinery covered approximately 430 acres and operated from 1904 until about 1982. The Amoco Refinery, addressed in this report, is located at 1000 North Sterling Road, in the City of Sugar Creek, Missouri, and was opened in 1904. The refinery closed in 1982. Dismantling began in 1986 and was completed in 1991. Storage tanks in Gerber Tank Farm are still used for product storage. During its seventy-eight (78) years of operation, the crude refining capacity expanded from about 12,000 barrels per day to a final capacity of some 100,000 barrels per day.

Sugar Creek, MO had a population of 3,982 in 1990; is located in Jackson County on the Missouri river, is located east/northeast of Kansas City, Mo., and is located at 39°08'N 94°24'W

As early as 1908, a water plant official form the city of Independence, Missouri, reported that the refinery was discharging materials to Sugar Creek, which were negatively impacting their Missouri River water supply. Ultimately, as a result of a shifting sand bar and wintertime conditions, the situation worsened, resulting in a lawsuit on/about 1920 against the refinery (known as Standard Oil at that time). By early as March 6, 1950, internal American Oil Company (later Amoco and now BP-Amoco) correspondence notes that oil (later identified more properly as gasoline) was reported in a spring on Burton Street, in the Sugar Creek neighborhood, south of the refinery. By 1953, tank leaks were documented as being responsible for oil leaks seen in this spring and creek (Sugar Creek) that flowed through the neighborhood. Available documentation that residents were complaining of gasoline odors, and of visible oil seen in the neighborhood, can be found as early as April 6, 1964. By 1982, it was estimated that as much as 8,232,000 gallons of oil had leaked into the ground and that approximately 1,900,000 gallons of free product had been recovered by various means from 1988 to 1995. A considerable amount of oil apparently remains in the ground. Data strongly suggests that the term “oil”, as it applies to oil contamination in/near Sugar Creek was premium leaded gasoline, known to contain up to 5% benzene. Other products have been shown to contain upwards of 15% benzene. Even after the initiation of remedial activities in 1997, groundwater benzene concentrations in the center of the petroleum plume were reported to be at levels up to 21.7 mg/L. Peak concentrations in groundwater under homes were up to 0.5 mg/L.

In forming these supplemental opinions on Mrs. Ryan’s benzene exposure, I have depended on information from the offices of Mr. Lon Walters, interviews with Mr. Ryan and her daughter Janie Everly and information from the published literature. The information that I have primarily considered and/or relied on is summarized in Appendix A. I have also relied on my knowledge and experience and training as a Chemical Engineer and Certified Industrial Hygienist (CIH), textbooks and reports on practices by industry for the design of oil/gas unit operations and systems and the control of petroleum contaminants and wastes and my risk assessment and work experience on petroleum contaminated sites.

I leave open the possibility of adding to or modifying my opinions, based on additional information I may receive or review.

Opinions:

My opinions regarding exposure are:

1. Mrs. Ryan's benzene exposure, while living at her homes on Evans and Huttig from 1956 to 1980, was 165 PPM-YRS.
2. Using a Monte Carlo simulation based on variations of exposure times, odor levels and the benzene content of gasoline, the range of likely exposures varied from 86 to 268 PPM-YRS.

Exposure Estimates:

An exposure estimate, resulting in PPM-YRS of benzene exposure was completed. The analysis is based on an assessment of Mrs. Ryan's exposure times while at/near her homes on 10317 Evans and 111 S. Huttig in Independence, MO along with benzene levels in air. The benzene levels in air are based on recollections of gasoline odors in air, odor thresholds, and the benzene content of gasoline. Details on the basis of these estimates, along with results of estimates, follow.

Estimates of Exposure Times:

Based on interrogatory responses and interviews, data on the time Mrs. Ryan spent at each location, along with her work history, are summarized in Table 1:

Table 1: Time History at Residences and Work History

Background Information:				
Resident History:				
Living Location:	Years:	Units	Timeframe:	
10317 Evans	3.8	years	12/56 to 9/60	
111 S. Huttig	44.2	years	9/60 to 11/04	
TOTAL	48.0	years		
Work History:				
Employer:	Years:	Units	Timeframe:	Hours/Week
BMA - Pershing Rd.	0.4	years	11/52 to 4/53	40
Not working	0.5	years	4/53 to 10/53	0

Background Information:				
Sears	1.3	years	10/53 to 2/55	40
Not working	10.2	years	2/55 to 4/65	0
H.E.M.	0.4	years	4/65 to 9/65	40
Not working	1.5	years	9/65 to 3/67	0
Montgomery Ward	0.3	years	3/67 to 6/67	40
Not working	0.5	years	6/67 to 1/68	0
Montgomery Ward	0.3	years	1/68 to 5/68	40
Not working	1.4	years	5/68 to 10/69	0
Loft Drive In	0.6	years	10/69 to 5/70	20
Not working	0.5	years	5/70 to 1/71	0
IRS	2.0	years	1/71 to 1/73	40
Not working	3.0	years	1/73 to 1/76	0
Milbank Manufacturer	4.0	years	1/76 to1/80	40

To calculate equivalent years for PPM-YRS for estimating exposures, a PPM-YR was estimated to be 124,800 minutes. This was based on the following assumptions:

Minutes per hour	60.0
Hours per day	8.0
Days per week	5.0
Weeks per year	52.0

The total minutes in a year was estimated to be 525,600.

Estimated exposure times at each resident are summarized in Table 2:

Table 2: Exposure Time Estimates and Assumption

Exposure Times At Residences:

Time frame	Years	Total Minutes	Work Hrs/Week	Work Min./Year	Vac. Min./Year	% Time @ Home	Net Home Min.	% Time Smelled Gasoline	Minutes @ Home Smelling Gasoline	Years (PPM) @ home
Evans Location:										
12/56 to 9/60	3.8	2,014,800	0	0	20,160	90%	1,743,768	90%	1,569,391	12.6
TOTAL										12.6
Huttig Location:										
Time frame	Years	Total Minutes	Work Hrs/Week	Work Min./Year		% Time @ Home	Net Home Min.	% Time Smelled Gasoline	Minutes @ Home	Years (PPM) @ home
									Smelling Gasoline	
9/60 to 4/65	4.6	2,409,000	0	0	20,160	85%	1,969,110	90%	1,772,199	14.2
4/65 to 9/65	0.4	219,000	40	120,000	20,160	85%	136,510	90%	122,859	1.0
9/65 to 3/67	1.5	788,400	0	0	20,160	85%	644,436	90%	579,992	4.6
3/67 to 6/67	0.3	131,400	40	120,000	20,160	85%	81,906	90%	73,715	0.6
6/67 to 1/68	0.6	306,600	0	0	20,160	85%	250,614	90%	225,553	1.8
1/68 to 5/68	0.3	175,200	40	120,000	20,160	85%	109,208	90%	98,287	0.8
5/68 to 10/69	1.4	744,600	0	0	20,160	85%	608,634	90%	547,771	4.4
10/69 to 5/70	0.6	306,600	20	60,000	20,160	85%	220,864	75%	165,648	1.3
5/70 to 1/71	0.7	350,400	0	0	20,160	85%	286,416	75%	214,812	1.7
1/71 to 1/73	2.0	1,051,200	40	120,000	20,160	85%	655,248	75%	491,436	3.9
1/73 to 1/76	3.0	1,576,800	0	0	20,160	85%	1,288,872	75%	966,654	7.7
1/76 to1/80	4.0	2,102,400	40	120,000	20,160	85%	1,310,496	75%	982,872	7.9
TOTAL										50.0
TOTAL YEARS (PPM-YEAR BASIS)										62.6

The total exposure time, in PPM-based years, was 62.6 years, accounting only for the period from December 1956 to January 1980. No exposure time was used beyond January 1980. These times account for the time Mrs. Ryan worked, and assume no exposure while at work. They also include an assumption of two weeks vacation per year and assume no exposure while on vacation. They also account for the amount of time she was at home, discounted for time she may have been away from the home and the time odors were present. She was home 90% of the time while at the Evans residence and home 85% of the time while at the S. Huttig residence. The percentage of times gasoline odors were smelled was reported to be 90% at both locations. I have been more conservative, dropping the percentages to 75% during the 1970s to reflect a period where environmental regulations began to take hold. Cells shaded in green were cells that contain a range of values for use in Monte Carlo analysis. The range used in the Monte Carlo analysis for these cells was always the value plus or minus five percent.

Estimates of Benzene Exposure PPM-YRS:

Using the exposure times discussed earlier, combined with odor threshold data from Drinker (see Appendix B for summary), and gasoline benzene content data collected from the literature (see Appendix C), a benzene exposure calculation was completed. Results of this calculation are shown in Table 3.

In interviews, both Mr. Ryan and his daughter repeatedly describe the gasoline odor as being "very strong".

A summary of odor responses by concentration (gasoline) from Drinker is shown below:

Concentration (ppm)	Odor Response(s)
140 - 160	Detectable odor; loss of odor beginning in as little as 1 hour; at 140 described as disinfectant by some subjects.
270	Detectable odor entire 8 hours; one subject had loss of odor after 6 hours
500	Detectable odor by all nine subjects; described as weak by 5 of 8 and strong by 3 of 8.
900	Detectable odor by all six subjects; 4 of 6 describe as strong.
2,600	Described as "very strong" by six subjects.
10,700 - 11,200	Detectable odor immediately

Based on the Drinker data, I have developed the following summary of concentrations by odor response for use in modeling Mrs. Ryan's benzene exposure:

Concentration (ppm)	Odor Response(s)
150	Weak, detectable odor
300	Moderate, detectable odor
600	Strong odor

This classification should be conservative based on the actual Drinker observations vs. concentrations.

A summary of the input and output of Mrs. Ryan's benzene exposure is provided in Table 3:

Table 3: Input and Output of Mrs. Ryan's Benzene Exposure

Living Location:	Time frame	Exposure Years:	Units	Described Odor Level	Gasoline Conc. (ppm)	Basis	Benzene Conc. (%)	Basis	Benzene Air Conc. - ppm	PPM-YRS
10317 Evans	12/56 to 9/60	12.6	years	Very strong	375	Use range of 150 to 600	2.75%	Amoco MSDS: 4% (used range of 0.5% to 5%) Ignores other feeds with higher %s	4.3	54.0
111 S. Huttig	9/60 to 4/65	14.2	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	36.6
111 S. Huttig	4/65 to 9/65	1.0	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	2.5
111 S. Huttig	9/65 to 3/67	4.6	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	12.0
111 S. Huttig	3/67 to 6/67	0.6	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	1.5
111 S. Huttig	6/67 to 1/68	1.8	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	4.7
111 S. Huttig	1/68 to 5/68	0.8	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	2.0
111 S. Huttig	5/68 to 10/69	4.4	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	11.3
111 S. Huttig	10/69 to 5/70	1.3	years	Very strong	225	Use range of 150 to 300	2.75%		2.6	3.4
111 S. Huttig	5/70 to 1/71	1.7	years	Very strong	150	Use value of 100 to 200	2.75%		1.7	3.0
111 S. Huttig	1/71 to 1/73	3.9	years	Very strong	150	Use value of 100 to 200	2.75%		1.7	6.8
111 S. Huttig	1/73 to 1/76	7.7	years	Very strong	150	Use value of 100 to 200	2.75%		1.7	13.3
111 S. Huttig	1/76 to1/80	7.9	years	Very strong	150	Use value of 100 to 200	2.75%		1.7	13.5
TOTAL										164.7

Benzene Concentration in Gasoline in Air:

Basis: Tironi and Hodgkins, 1991, App. Occup. Environ. Hyg., Compliance with the OSHA Benzene Permissible Exposure Limit (PEL) at the Gasoline Vapor PEL

Benzene content of liquid gasoline for 1990 was 1.7 (winter) and 1.5 (summer) for an average of 1.6

Benzene content of gasoline vapor was 1.0 (avg.) ppm for 150 ppm gasoline and 2.0 ppm for 300 ppm gasoline.

Calculation: (Benzene content of liquid/1.6)*(Gasoline in air conc. - ppm/150)

The total predicted benzene exposure was 165 PPM-YRS. Note that this assumes declining, conservative values for gasoline concentrations with time. Also, the percent benzene value used was 2.75% rather than the 4.0% seen in Amoco MSDS sheets. This reflects a range of values seen in the literature (see Appendix C). The enhancement factor has been replaced by airborne benzene levels in air, based on work by Tironi and Hodgkins. Again, the green-color cells contain a range of values discussed later in the Monte Carlo exposure section below.

Estimates of Benzene Exposure PPM-YRS – Monte Carlo Analysis:

It is constructive to look at the effect of varying key parameters to determine their impact on results, in this case benzene exposure. To accomplish this, a program called Crystal Ball™ was utilized. It is an add-on program to Microsoft Excel™ and is accessed as a custom tool bar.

Variables allowed varying, and the degree to which they were varied, are summarized below:

Variable:	Range of Values Considered:
Percent Time at Home	Mean plus or minus 5%
Percent Time Smelled Gasoline	Mean plus or minus 5%
Gasoline Concentration	For value of 375, range used was 150 to 600
	For value of 225, range used was 150 to 300
	For value of 150, range used was 100 to 200

Benzene percentage in gasoline for means of 2.75%, range used was 0.5% to 5%. Amoco memorandum from Gorp and Kaplan suggest that the range in this analysis conservatively covers the range of benzene in Amoco gasoline. Note that Gorp reported benzene levels in Amoco gasoline as high as 5.4% benzene by volume.

Each range of values was considered to be distributed normally.

The simulation was run 10,000 times. Output from this simulation is summarized in Figure 1 and Table 4:

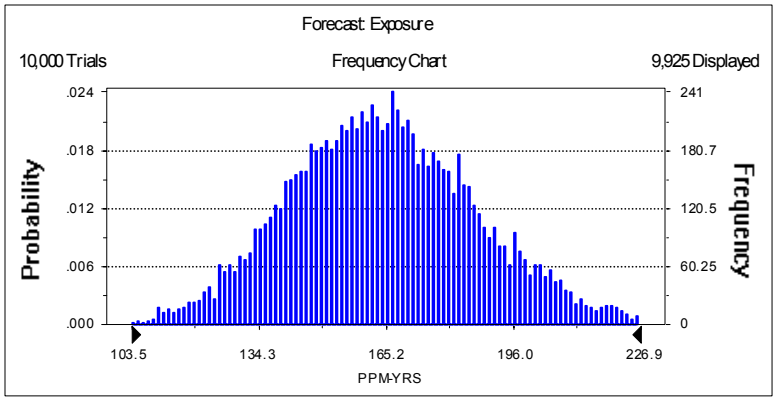

Figure 1: Simulated Benzene Exposure (PPM-YRS)

The range of exposures calculated was from 86 PPM-YRS to 268 PPM-YRS. Statistics and percentiles from the simulation are summarized in Table 4.

Table 4: Exposure Simulation Statistics and Percentiles

Statistics:	Forecast values
Trials	10,000
Mean	164.8
Median	163.9
Mode	---
Standard Deviation	23.0
Variance	529.0
Skewness	0.22
Kurtosis	3.03
Coeff. of Variability	0.14
Minimum	85.5
Maximum	267.5
Range Width	182.0
Mean Std. Error	0.23
Percentiles:	**Forecast values**
0%	85.5
10%	136.3
20%	145.1
30%	152.1
40%	158.2
50%	163.9
60%	169.6
70%	176.2
80%	183.8
90%	195.3
100%	267.5

Discussion:

Several inputs to these calculations were adjusted to ensure conservatism in the results. Factors contributing to this conservatism were:

- No exposure was assumed from 1980 to late 2004.
- No exposure was assumed while at work.
- The percent time smelling gasoline was adjusted down in the later years below the 90% reported by Mr. Leonard Ryan and Ms. Janie Everly (his daughter).
- The gasoline concentrations used from Drinker in the model were well below those that could have been used for a strong odor as reported by Mr. Leonard Ryan and Ms. Janie Everly.
- The percentage of benzene in gasoline used (2.75%) in the calculations was less than that (4%) reported in Amoco MSDS sheets.
- The results do not reflect other fuels that were also reportedly released, some of which have benzene concentrations as high as 15%.

Closing:

EES appreciates the opportunity to provide these professional services for the Walters Law Firm, LLC. If you have any questions regarding this case or require further information, please do not hesitate to call our office.

Thank you,

Stephen Petty, P.E., C.I.H.
President

APPENDIX A

References

American Industrial Hygiene Association. (AIHA). 1997. Odor Thresholds for Chemicals with Established Occupational Health Standards, Fairfax, VA.

Amoco memorandum from G.S. Van Gorp to T. E. Kupferer dated August 12, 1981 (Amoco # 48218 and File # SC078698)

Amoco memorandum from Mr. Kaplan to distribution dated August 22, 1963 (Amoco # 48218 and File # SC078698)

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May, J. 1966. Odor Thresholds of Solvents for Assessment of Solvent Odors in the Air. Staub 26: 385-389 (English translation of German article)

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Telephone Log – April 13, 2005. Telecom with Janie Everly.

Tironi, G., and D. G. Hodgkins. 1991. Compliance with OSHA Benzene Permissible Exposure Limit (PEL) at the Gasoline Vapor PEL, Appl. Occup. Environ. Hyg., 6(10), October, pgs. 881-884.

W.L. Nelson. 1958. Petroleum Refinery Engineering, Fourth Edition, McGraw-Hill Book Company, New York, NY.

APPENDIX B

Summary of Drinker (1943) Study

Summary of Previous Work:

According to a study involving three subjects conducted by the Bureau of Mines in 1921, it was determined that gasoline is a very innocuous substance that will cause different effects on an individual based on the concentration inhaled. The study results indicate that:

- 700 to 2800 ppm concentrations of gasoline vapor caused dizziness within 14 ½ minutes.
- 11300 to 22200 ppm concentrations of gasoline vapor caused great dizziness in 3 minutes.
- 22200 to 26000 ppm concentrations of gasoline vapor made a man dizzy after 10 to 12 breaths

In 1927, these experiments were repeated with results indicating:

- 1000 ppm concentrations of gasoline vapor caused mild symptoms of dullness, unsteadiness, and giddiness within 50 minutes.
- 3000 ppm concentrations of gasoline vapor caused slight irritation of the eyes and moderate symptoms of dizziness within 30 minutes.
- 7000 ppm concentrations of gasoline vapor caused coughing, marked irritation of the eyes and nose, numbness in the legs and unsteadiness within 10 minutes.

In 1922, O. M. Spencer reported on a group of workers exposed to vapors of whole gasoline while wiping off moving belts with gasoline. According to Spencer's report, complaints in order of frequency involved: eye irritation, headaches, drowsiness, heaviness in the head and fatigue.

It was concluded by investigators from all three studies that no relation exists between the possible effects of exposure and the quality of gasoline.

Current Work:

In 1942, an experiment was conducted using two gasolines brought out in analysis from commercial colorless lead-free gasoline. The two gasolines were: Commercial Gasoline (100F to 400F cut) and a Light Fraction of Commercial Gasoline (100F to 110F Cut). The study consisted of nine experiments. Seven experiments were carried out in a specially designed room in which the temperature, humidity and ventilation rates could be accurately controlled. Subjects within the room were exposed to different concentrations of the two gasolines to determine the health effect of exposure at different levels. The final two experiments consisted of the two gasolines being delivered steadily in specific concentrations into an air-line, where it was vaporized through a face mask held by the subject over his/her nose and face.

The following two tables present a summary of each experiment that identifies the test substance used, concentration levels, experiment duration, subject information, noted observations of odor thresholds, noted health effects of exposure and complaints made by the test subjects.

TABLE 1: COMMERCIAL GASOLINE

CONC. LEVELS	EXPOSURE DURATIONS	NOTED OBSERVATIONS	HEALTH EFFECTS
160 ppm (Subjects were exposed to commercial gasoline uniformly distributed through the test areas ventilation system)	8 hours	Detectable odor upon entering area (majority of subjects experienced a loss of odor after 1, 3 and 7 hours). Subjects included 8 women, age 17 to 32	*Examination* ➢ Hyperemia of the conjunctiva vessels ➢ No redness of throat was noted. *Complaints* ➢ Loss of appetite ➢ Sickness at stomach ➢ Headache ➢ Cough/Throat irritation ➢ Irritation/Itching of eyes
270 ppm (Subjects were exposed to commercial gasoline uniformly distributed through the test areas ventilation system)	8 hours	Detectable odor entire duration upon first entering area (one subject experienced a loss of odor after 6 hours). Subjects included 13 men, age 23 to 45	*Examination* ➢ Slight hyperemia of the conjunctiva vessels. ➢ Distinct hyperemia of the throat. *Complaints* ➢ Loss of appetite ➢ Dizziness ➢ Sickness at stomach ➢ Cough/Throat irritation ➢ Irritation/Itching of eyes
11,200 ppm (Commercial gasoline was delivered steadily into an air-line, where it was vaporized through a face mask held by the subject over his/her nose and face)	5 to 5.5 minutes (test was terminated voluntarily)	Detectable odor immediately Subjects included 3 men and 1 woman, age 29 to 45	*Examination* ➢ Dizziness ➢ Incoordination and drunkenness ➢ Cough and sneezing *Complaints* ➢ Severe nose and throat irritation after 20 seconds to 1 minute.

TABLE 2: LIGHT FRACTION OF COMMERCIAL GASOLINE			
CONC. LEVELS	**EXPOSURE DURATIONS**	**NOTED ODOR OBSERVATIONS MADE BY SUBJECTS**	**HEALTH EFFECTS**
140 ppm (Subjects were exposed to a light fraction of commercial gasoline uniformly distributed through the test areas ventilation system)	8 hours	Detectable odor upon entering area. ➢ Described as gasoline by 8 of 10 subjects. ➢ Described as some sort of disinfectant by 2 of 10 subjects. Subjects included 10 college girls, age 17 to 22	*Examination* ➢ N/A *Complaints* ➢ Slight sickness at stomach ➢ Slight headache ➢ Slight cough/throat irritation ➢ Slight drowsiness ➢ Slight irritation/itching of eyes
150 ppm (Subjects were exposed to a light fraction of commercial gasoline uniformly distributed through the test areas ventilation system)	8 hours	Detectable odor entire duration upon first entering area. ➢ Described as weak by 5 of 8 subjects. ➢ Described as strong by 3 of 8 subjects. (Four subjects experienced a loss of odor. Three after 2 hours and one late in the afternoon). Subjects included 8 women, age 17 to 32	*Examination* ➢ N/A *Complaints* ➢ Loss of appetite ➢ Sickness at stomach ➢ Headache ➢ Cough/Throat irritation ➢ Very slight irritation/itching of eyes
500 ppm (Subjects were exposed to a light fraction of commercial gasoline uniformly distributed through the test areas ventilation system)	1 hour	Detectable odor entire duration upon first entering area. ➢ Described as weak by 3 of 9 subjects. ➢ Described as strong by 2 of 9 subjects. ➢ 4 of 9 subjects made no	*Examination* ➢ N/A *Complaints* ➢ Headache ➢ Cough/Throat irritation ➢ Irritation/itching of eyes

TABLE 2: LIGHT FRACTION OF COMMERCIAL GASOLINE			
CONC. LEVELS	**EXPOSURE DURATIONS**	**NOTED ODOR OBSERVATIONS MADE BY SUBJECTS**	**HEALTH EFFECTS**
		comments. Subjects included 9 men, age 23 to 45	
900 ppm (Subjects were exposed to a light fraction of commercial gasoline uniformly distributed through the test areas ventilation system)	1 hour	Detectable odor within area (one subject indicated that the odor was stronger than previous day but other five subjects could not detect same). ➢ Described as strong by 4 of 6 subjects. ➢ 2 of 6 subjects made no comments. Subjects included 6 men, age 23 to 45	*Examination* ➢ Dizziness and unsteadiness *Complaints* ➢ Dizziness was not experienced, however, two subjects the following morning experienced unsteadiness of gait and uncertainty in driving. ➢ Slight nose/throat irritation ➢ Slight irritation/itching of eyes
2600 ppm (Subjects were exposed to a light fraction of commercial gasoline uniformly distributed through the test areas ventilation system)	1 hour	"Very Strong" Detectable gasoline odor upon first entering area but strength could not be estimated (one subject experienced a loss of odor after 6 hours). Subjects included 5 men and 1 women, age 23 to 45	*Examination* ➢ Mild intoxication ➢ Small amount of muscle incoordination ➢ Difficulty accurately reading gauges ➢ Light-headedness with no headaches or disagreeable sensations ➢ No unpleasant after-effects *Complaints* ➢ Dizziness without mark incoordination ➢ Sickness at stomach (one subject left room due to nausea after 13 minutes). ➢ Cough/Throat irritation ➢ Irritation/Itching of eyes (was experienced at beginning of experiment but rapidly disappeared) ➢ Two subject reported tasting and smelling gasoline the following morning

TABLE 2: LIGHT FRACTION OF COMMERCIAL GASOLINE			
CONC. LEVELS	**EXPOSURE DURATIONS**	**NOTED ODOR OBSERVATIONS MADE BY SUBJECTS**	**HEALTH EFFECTS**
10,700 ppm (A light fraction of commercial gasoline was delivered steadily into an air-line, where it was vaporized through a face mask held by the subject over his/her nose and face)	2 to 7.1 minutes	Detectable odor immediately Subjects included 4 men, age 37 to 45	*Examination* ➢ Dizziness and visible unsteadiness was observed within 4 minutes ➢ In-coordination and drunkenness ➢ Two subjects were distinctly hilarious and very active. ➢ Acute effects appeared to wear off in a short time with no objectionable after-experiences. *Complaints* ➢ Severe nose and throat irritation after 2 minutes. ➢ Incoordination and drunkenness occurred in three subjects within 4 to 5 minutes and one subject within 7 minutes 10 seconds.

(Philip Drinker, C.P. Yaglou and Madeleine Field Warren, 1943. “The Threshold Toxicity of Gasoline Vapor”, The Journal of Industrial Hygiene and Toxicology, Volume 25, pp.225-232, January 1943 – December 1943.)

APPENDIX C

Benzene Content of Gasoline and Naphtha – Literature Values

BENZENE CONCENTRATIONS IN GASOLINE BY YEAR

YEAR	% BENZENE	REFERENCE
1974	<1	(Runion, Howard E.; "Benzene in Gasoline", American Industrial Hygiene Association Journal, Vol. 36, p.338, 1975.)
1975	<2	(Runion, Howard E.; "Benzene in Gasoline", American Industrial Hygiene Association Journal, Vol. 36, p.338, 1975.)
1976	.54 – 2.39	(Runion, Howard E.; "Benzene in Gasoline", American Industrial Hygiene Association Journal, Vol. 36, p.338, 1975.)
1977	>1	(Testimony of R.J. Comeaux, July 11, 1977, Vice President of Gulf Oil Company)
1977	1.1 - 4	(Testimony of R.S. Proctor – Chevron - before the OSHA committee reviewing the proposed revised permanent standard for occupational exposure to benzene on July 11, 1977 – OSHA Docket H-059)
1977	0.86	Mobile Premium Gasoline - (Memo from W. F. Hergrueter to P.R. Carl dated October 4, 1977. Source Monitoring of Marine Emissions of Benzene, Technical Service Laboratories, Mobil Technical Center, Princeton, N.J.)
1978	0.2 – 4.8	(McDermott, H.J. and S.E. Killiany, Jr.; "Quest for a Gasoline TLV", American Industrial Hygiene Association Journal, Vol. 39, pp. 110-117, Feb. 1978.)
1988	4	AMOCO Oil Co.- AMOCO Regular Leaded Gasoline Material Safety Data Sheet, – 9130-00-264-6218, http://hazard.com/msds/f2/bgw/bgwpv.html
1988	2.7	Regular – Leaded Gasoline, (Letter from R.E. Green to C.F. Grimmer, Shell Oil Company Interoffice Memorandum, February 29, 1988, Table III, p. 6)
1988	1.30	Regular – Leaded Gasoline, (Letter from R. K. Jones to D. E. Eitel, Shell Oil Company Interoffice Memorandum, March 28, 1988, p. 1-2)
1988	3.0	RU-2000, (Letter from R.E. Green to C.F. Grimmer, Shell Oil Company Interoffice Memorandum, February 29, 1988, Table III, p. 6)
1988	1.21	RU-2000, (Letter from R. K. Jones to D. E. Eitel, Shell Oil Company Interoffice Memorandum, March 28, 1988, p. 2)
1988	2.8	SU-2000, (Letter from R.E. Green to C.F. Grimmer, Shell Oil Company Interoffice Memorandum, February 29, 1988, Table III, p. 6)
1988	1.10 – 1.58	SU-2000, (Letter from R. K. Jones to D. E. Eitel, Shell Oil Company Interoffice Memorandum, March 28, 1988, p. 1-2)

YEAR	% BENZENE	REFERENCE
1988	2.55	SU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	5.29	RU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.91	Shell Regular, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.25	SU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	5.42	RU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.84	Shell Regular, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	2.96	SU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.65	Shell Regular, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	2.96	SU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.64	Shell Regular, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.86	SU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.63	Shell Regular, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.90	SU2000, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1988	4.64	Shell Regular, (Letter from T. A. Colangelo to C. F. Grimmer, Shell Oil Company Interoffice Memorandum, April 4, 1988, p. 14)
1989	2.1	(Page, Norbert P. and Myron Mehlman; “Health Effects of Gasoline Refueling Vapors and Measured Exposures at Service Stations”, Toxicology and Industrial Health, Vol. 5, No. 5, pp. 869-890, 1989.)
1989	3.2	(Air Force, Chemical and Physical Information, Table 3-3 Major Components of Gasoline, 1989)
1990	0.95	http://www.chevron.com/prodserv/fuels/bulletin/fed-refm/rfg-char.shtml
1991	1.35 – 1.70	Premium Gasoline - (Tironi, Gene and D. G. Hodgkins. 1991. *Compliance with the OSHA Benzene Permissible Exposure Limit (PEL) at the Gasoline Vapor PEL*, Appl. Occup. Environ. Hyg., Vol.

YEAR	% BENZENE	REFERENCE
		6, No. 10., pp. 881-884, October)
1991	1.38 – 1.73	Regular Gasoline - (Tironi, Gene and D. G. Hodgkins. 1991. *Compliance with the OSHA Benzene Permissible Exposure Limit (PEL) at the Gasoline Vapor PEL*, Appl. Occup. Environ. Hyg., Vol. 6, No. 10., pp. 881-884, October)
1991	0-5	(Shell Products Containing Benzene or Benzene Compounds, November 13, 1991, pgs. 3-8).
1991	<5	Recovered Gasoline, Shell Products Containing Benzene or Benzene Compounds, November 13, 1991, pg. 4
1993	1 - 5	(Employee Benzene Exposure Assessment Summary Report Barge Operations, Bruce B. Crowell, Ashland Petroleum Company, April 1, 1993)
1993	4	AMOCO Oil – Regular Lead- Free Gasoline – Gasoline, Automotive Material Safety Data Sheet, http://home.att.net/~weltanco/msds/gasoline.htm
1994	1.6	http://www.ec.gc.ca/energ/fuels/reports/benz_99/benz_1999_e.pdf
1994	3.5	http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/fr309.pdf
1995	1.4	http://www.ec.gc.ca/energ/fuels/reports/benz_99/benz_1999_e.pdf
1995	2	http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/fr309.pdf
1996	1.6	http://www.ec.gc.ca/energ/fuels/reports/benz_99/benz_1999_e.pdf
1997	1.5	http://www.ec.gc.ca/energ/fuels/reports/benz_99/benz_1999_e.pdf
1998	1.6	http://www.ec.gc.ca/energ/fuels/reports/benz_99/benz_1999_e.pdf
1998	1	http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/fr309.pdf
2005	0.1 - 4	http://www.kemi.se/kemamne_eng/benzen_eng.htm
?	1.2 to 4.9	http://www.prod.exxon.com/exxon_gas/conv-exxon.html

OUTLINE OF
BENZENE CONCENTRATIONS IN NAPHTHA BY YEAR

YEAR	% BENZENE	REFERENCE
1961	9.3	(Pagnotto, Leonard, D., et. al., 1961. "Industrial Benzene Exposure from Petroleum Naphtha: I. Rubber Coating Industry", American Industrial Hygiene Journal, Vol. 22, pp. 417-421, Dec.)
1963	1.6 – 2.8	(Elkins, Hervey, B., et. al., 1963. "Industrial Benzene Exposure from Petroleum Naphtha", American Industrial Hygiene Journal, pp. 99-102, Mar-Apr.)
1977	>1	Naphtha solvents and Naphtha-based (type B) jet fuels, (Testimony of R.J. Comeaux, July 11, 1977, Vice President of Gulf Oil Company)
1977	0.1	Kerosene and light fuel oils, (Testimony of R.J. Comeaux, July 11, 1977, Vice President of Gulf Oil Company)
1991	1 - 18	Naphtha – Algerian, (Shell Products Containing Benzene or Benzene Compounds, November 13, 1991, pg. 1)
1991	1 - 5	Naphtha – Cutback Diluent, (Shell Products Containing Benzene or Benzene Compounds, November 13, 1991, pg. 3)
1991	<5	Naphtha – Distilling Light, (Shell Products Containing Benzene or Benzene Compounds, November 13, 1991, pg. 1)