



REFERENCES

- Agency for Toxic Substances and Disease Registry[ATSDR], 1997. TOXFAQsTM for Methyl tert-Butyl Ether (MTBE).[Online] Available from <http://www.atsdr.cdc.gov/tfacts91.html>
- American Petroleum institute, 1998. Hazardous air Pollutant Emissions from Gasoline Loading Operations at Bulk Gasoline terminals, (API publication no. 347, 1998)
- Ballik, 1997. Operating manual analyzer FID PM-2000. Documentation FID PM 2000, HC Analyzer. , Pierburg: 3.3-3.13
- Baoning Z., 2002. Photochemical smog modeling for air quality management in tropical climate: case study. Doctoral dissertation, School of Environment, Resources and Development, Asian Institute of Technology.
- Buchholz, R.,A. et al. 1998. Principles of environmental management, . 2nd ed. New York : Prentice Hall. : 142-146
- Canada's National Occupational Health & Safety Resource, 1997. Health Effects of Toluene, OHA Answer.
- Congressional Research Service, 1982. Air Pollution Impacts Impacts On Agriculture And Forestry. Library of Congress. Cited in in Michael P.Walsh. Vapor Emission form Gasoline Transport, Storage and Refueling in Bangkok. National Energy Policy Office of Thailand
- Connecticut Academy of Science and Engineering (CASE), 1999. MTBE Found to Reduce Carbon Monoxide Levels, CASE Study Reports No Quantifiable Effect on Ozone Levels, Public Health
- Cool Sorption(Thailand), 2000. Vapour Recovery Process Manual, Activated carbon, vacuum regenerated adsorption (CVA) process,
- Davis, W.T.,ed. 2000 Air Pollution Engineering Manual 2nd ed. New York :John Wiley&Sons.
- Department of Public and Municipal Works, 2000. Gasoline Terminal Name List of 2000.

- Energy Policy and Planning Division, 2001. 2001 Energy Report : Thai Energy Situation, Policies and Measures, National energy policy Office[Online] Available from: <http://www.nepo.go.th/doc/>
- European Parliament and Council Directive 94/63/EC, 1994. The control of volatile organic compound (VOC) emissions resulting from the storage of petrol and its distribution from terminals to service stations. European Parliament and Council of the European Union, Official Journal of the European Communities No L 365 (1994)
- Fuel Pipeline Transportation, 2001. Vapor recovery unit manual No1, Operation and Maintenance Manual Project. Fuel Pipeline Transportation Limited
- Institute of Petroleum, Marketing Committee London , 1992. Guidelines for the design and operation of gasoline vapor emission controls, : 18-24
- Kenneth Wark, Cecil F. Warner, and Wayne T. Davis, 1998. Air Pollution : Its Origin and Control. 3rd ed., USA Addison-Wesley Longman.
- Notification of the Ministry of Science, Technology and Environment, Standard of gasoline vapor emission at gasoline bulk terminals, dated June 20, B.E.2544 (2001), published in the Royal Government Gazette, Vol. 118 Special part 58 dated June 18, B.E.2544 (2001)
- Notification of the Ministry of Commerce, The Quality of Gasoline, dated January 13, 1998
- Office of Air Quality planning & Standard USEPA, 2000. Method 18 –Measurement of gaseous organic compound emissions by gas chromatography, EMC - CFR Promulgated Test Methods (TM) :1048-1118
- Panich S., Walsh,M.P. and Kishan S. ,1995. Vapor emission from gasoline transport, storage and refuelling in Bangkok. Final report, National Energy Policy Office
- Pinit Boonsenan, 2003. March 3, Depot Manger, Fuel Pipeline Transportation Limited. Interview.
- Pollution Control Department Thailand [PCD], 2000. Air Emission Source Database Update and Ambient Air Quality Impact Assessment in Bangkok Metropolitan Region. PCD 03-034. ISBN 974-7879-10-7

- PCD, 2001. Investigation and Analysis of precursor for the Mitigation of Photochemical Air Pollution in Bangkok, Final report. Volume4/4
- Petroleum Institute of Thailand, 2000. Memorandum. Progress report of increasing cost in order to vapor recovery unit implemented. February 10, 2000
- Sunan Chanfun, 2003 February 29. Senior Instrument Engineer. The Shell Company of Thailand Limited Interview.
- S. Wongwises, I. Rattanaprayura and S.Chanchaona, 1997. An Evaluation of Evaporative Emissions of Gasoline from Storage Sites and Service Stations. Department of Mechanical Engineering, King Mongkut's Institute of Technology Thonburi.
- Shell Bangkok Thailand, 2001. Vapor recovery unit manual No1, Operation and Maintenance Manual Project. The Shell company of Thailand
- U.S. Department of health and human Services, 2002. 10th Report on Carcinogens; Benzene. National Toxicology Program
- U.S. Environmental Protection Agency[U.S.EPA], 1978. Air Quality Criteria For Ozone Other Photochemical Oxidants. Cited in Michael P.Walsh. Vapor Emission form Gasoline Transport, Storage and Refueling in Bangkok. National Energy Policy Office of Thailand
- U.S.EPA, 1996. National air quality and emissions trends report.
- U.S.EPA Office of Air Quality Planning and Standards, 1994. Gasoline Distribution Industry (Stage I)- Background Information for Proposed Standards
- U.S.EPA, 40 CFR 63, 1994. National Emission Standards for Hazardous Air Pollutants for Source Category: Gasoline Distribution (Stage I), Proposed Rule
- U.S.EPA, 1998, 40 CFR Part 63, National Emission Standards for Hazardous Air Pollutants for Source Category: Gasoline Distribution (Stage I),[Online] Available from: <http://www.epa.gov/ttn/uatw/gasdist/fr08fe94.txt>
- U.S.EPA, 2000. Integrated Risk Information System (IRIS), Benzene [Online]. Available from : <http://ehp.niehs.nih.gov/roc/tenth/profiles/so19benze.pdf>. [2003, February 29]

U.S.EPA, 2001. Ground-level Ozone (Smog), Ozone Control Strategies.[Online]

Available from:<http://www.epa.gov/region01/eco/airqual/strategy.html>

U.S.EPA Natural gas STAR Program, 2002. Lessons Learned from Natural Gas STAR Partners Installing Vapor Recovery Units on Clude Oil Storage Tanks, [Online]

U.S.EPA(2002) Available from:<http://www.epa.gov/gasstar/install.htm>

U.S.EPA, 2002. Health and environmental Effects of Ground-Level Ozone, Fact sheet. U.S.EOA Office of Air & Radiation [OAR], Office of Air Quality Planning & Standard

World Health Organization, 1996. Environmental Health Criteria, No 186,

Ethylbenzene. ISBN: 92 4 157186 1

World Health Organization, 1997. Environmental Health Criteria, No 190, Xylene.

ISBN: 92 4 157190 X

World Health Organization, 1996. Environmental Health Criteria, No 206, Methyl

Tertiary-butyl Ether. ISBN: 92 4 157206 X

APPENDIX A

APPENDIX A

Calibration Curve of BTEX and MTBE

=====
Calibration Table
=====

Calib. Data Modified : 2/4/03 12:31:12 PM

Calculate : External Standard
Based on : Peak Area

Rel. Reference Window : 5.000 %
Abs. Reference Window : 0.000 min
Rel. Non-ref. Window : 5.000 %
Abs. Non-ref. Window : 0.000 min
Uncalibrated Peaks : not reported
Partial Calibration : Yes, identified peaks are recalibrated
Correct All Ret. Times: No, only for identified peaks

Curve Type : Linear
Origin : Forced
Weight : Equal

Recalibration Settings:
Average Response : Average all calibrations
Average Retention Time: Floating Average New 75%

Calibration Report Options :

Printout of recalibrations within a sequence:

Calibration Table after Recalibration

Normal Report after Recalibration

If the sequence is done with bracketing:

Results of first cycle (ending previous bracket)

Signal 1: FID1 A,

| RetTime [min] | Lvl Sig | Amount [ug] | Area | Amt/Area | Ref Grp Name |
|------------------|------------|----------------|----------|----------|--------------|
| 6.575 | 1 1 | 9.90100 | 1.12959 | 8.76509 | MTBE |
| | 2 | 47.61900 | 6.55217 | 7.26767 | |
| | 3 | 90.90900 | 14.05666 | 6.46733 | |
| | 4 | 230.77000 | 36.09025 | 6.39425 | |
| 8.945 | 1 5 | 4.97500 | 1.64325 | 3.02753 | BENZENE |
| | 1 | 9.90100 | 2.27270 | 4.35649 | |
| | 2 | 47.61900 | 11.57973 | 4.11227 | |
| | 3 | 90.90900 | 23.97835 | 3.79130 | |
| | 4 | 230.77000 | 59.72768 | 3.86370 | |

| RetTime [min] | Lvl Sig | Amount [ug] | Area | Amt/Area | Ref Grp Name |
|------------------|------------|----------------|----------|----------|--------------|
| 12.671 | 1 5 | 4.97500 | 1.33320 | 3.73163 | TOLUENE |
| | 1 | 9.90100 | 2.32718 | 4.25451 | |
| | 2 | 47.61900 | 12.21735 | 3.89765 | |
| | 3 | 90.90900 | 25.31466 | 3.59116 | |
| | 4 | 230.77000 | 64.29553 | 3.58921 | |
| 16.401 | 1 5 | 4.97500 | 1.40644 | 3.53730 | ETHYLBENZENE |
| | 1 | 9.90100 | 2.38735 | 4.14727 | |
| | 2 | 47.61900 | 12.87799 | 3.69770 | |
| | 3 | 90.90900 | 25.95047 | 3.50317 | |
| | 4 | 230.77000 | 67.51861 | 3.41787 | |
| 16.696 | 1 5 | 4.97500 | 1.35628 | 3.66813 | M-XYLENE |
| | 1 | 9.90100 | 2.53936 | 3.89901 | |
| | 2 | 47.61900 | 13.31071 | 3.57750 | |
| | 3 | 90.90900 | 26.75976 | 3.39723 | |
| | 4 | 230.77000 | 69.24318 | 3.33275 | |
| 17.550 | 1 5 | 4.97500 | 1.62161 | 3.06794 | O-XYLENE |
| | 1 | 9.90100 | 2.74222 | 3.61057 | |
| | 2 | 47.61900 | 13.61374 | 3.49786 | |
| | 3 | 90.90900 | 27.38919 | 3.31916 | |
| | 4 | 230.77000 | 70.53236 | 3.27183 | |

2 Warnings or Errors :

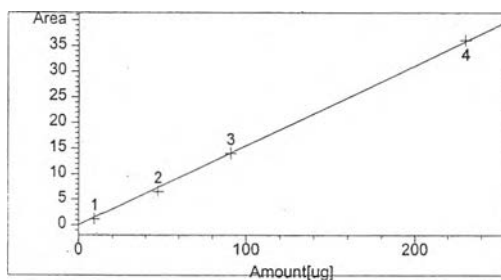
Warning : Overlapping peak time windows at 16.401 min, signal 1

Warning : Overlapping peak time windows at 16.696 min, signal 1

=====
Peak Sum Table
=====

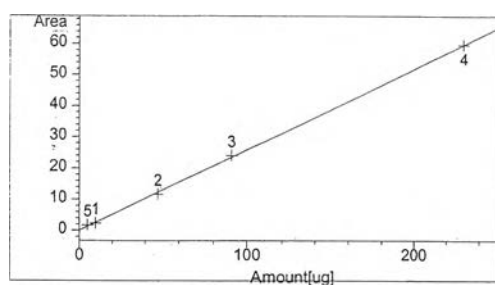
No Entries in table

=====
Calibration Curves
=====

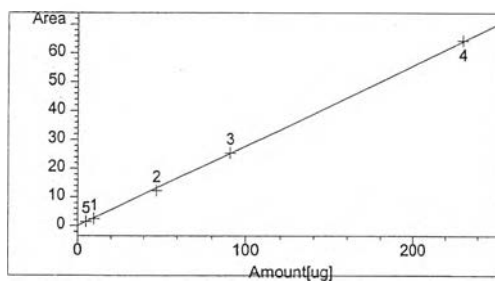


MTBE at exp. RT: 6.575
FID1 A,
Correlation: 0.99969
Residual Std. Dev.: 0.56074
Formula: $y = mx$
m: 1.55430e-1
x: Amount [ug]
y: Area

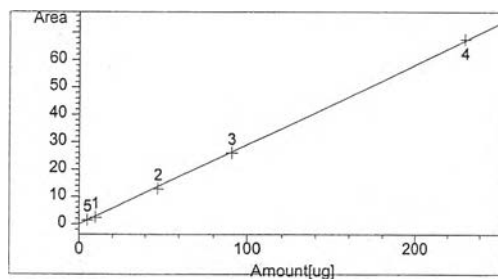
Method C:\HPCHEM\1\METHODS\CU2.M



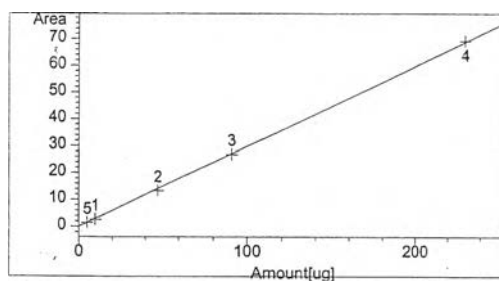
BENZENE at exp. RT: 8.945
 FID1 A,
 Correlation: 0.99989
 Residual Std. Dev.: 0.49171
 Formula: $y = mx$
 m: $2.58886e-1$
 x: Amount [ug]
 y: Area



TOLUENE at exp. RT: 12.671
 FID1 A,
 Correlation: 0.99987
 Residual Std. Dev.: 0.55738
 Formula: $y = mx$
 m: $2.77740e-1$
 x: Amount [ug]
 y: Area

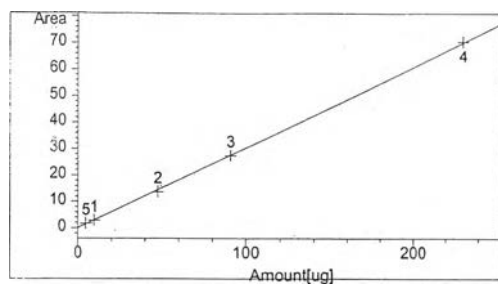


ETHYLBENZENE at exp. RT: 16.401
 FID1 A,
 Correlation: 0.99985
 Residual Std. Dev.: 0.63016
 Formula: $y = mx$
 m: $2.90790e-1$
 x: Amount [ug]
 y: Area



M-XYLENE at exp. RT: 16.696
 FID1 A,
 Correlation: 0.99989
 Residual Std. Dev.: 0.56488
 Formula: $y = mx$
 m: $2.98511e-1$
 x: Amount [ug]
 y: Area

Method C:\HPCHEM\1\METHODS\CU2.M



O-XYLENE at exp. RT: 17.550

FID1 A,

Correlation: 0.99991

Residual Std. Dev.: 0.50602

Formula: $y = mx$

m: $3.04339e-1$

x: Amount [ug]

y: Area

=====

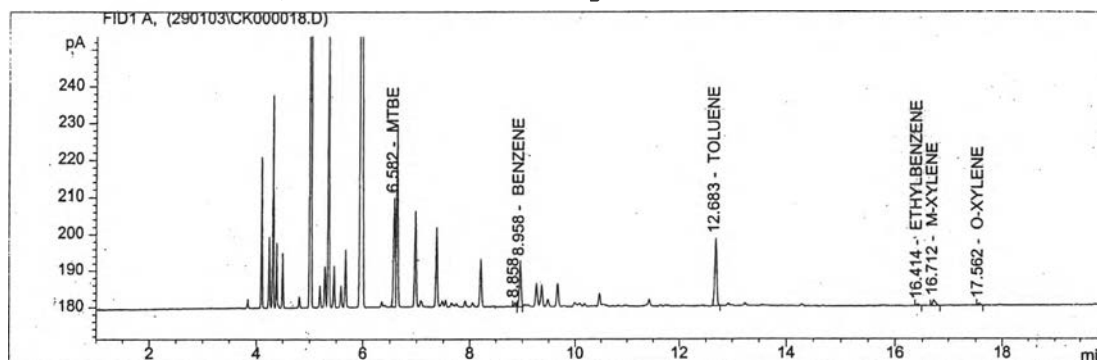
Chromatogram of BTEX and MTBE

```

=====
Injection Date   : 1/30/03 1:17:45 AM           Seq. Line :   18
Sample Name     : front7                       Vial      :   17
Acq. Operator   : Chanpen                      Inj       :    1
                                           Inj Volume: 1 µl

Acq. Method     : C:\HPCHEM\1\METHODS\CU2.M
Last changed    : 1/29/03 2:52:26 PM by Chanpen
Analysis Method : C:\HPCHEM\1\METHODS\CU2.M
Last changed    : 2/4/03 12:18:20 PM by somkiat
                  (modified after loading)
=====

```



External Standard Report

```

=====
Sorted By       : Signal
Calib. Data Modified : 2/4/03 11:15:14 AM
Multiplier      : 1.0000
Dilution        : 1.0000
=====

```

Signal 1: FID1 A,

| RetTime [min] | Type | Area [pA*s] | Amt/Area | Amount [ug] | Grp | Name |
|---------------|------|-------------|----------|-------------|-----|--------------|
| 6.582 | BV | 63.10792 | 6.43377 | 406.02169 | | MTBE |
| 8.958 | VBA | 28.40019 | 3.86270 | 109.70155 | | BENZENE |
| 12.683 | BB | 47.19960 | 3.60049 | 169.94155 | | TOLUENE |
| 16.414 | BP | 1.42584 | 3.43891 | 4.90332 | | ETHYLBENZENE |
| 16.712 | PB | 6.41595 | 3.34997 | 21.49322 | | M-XYLENE |
| 17.562 | BP | 1.67009 | 3.28581 | 5.48760 | | O-XYLENE |

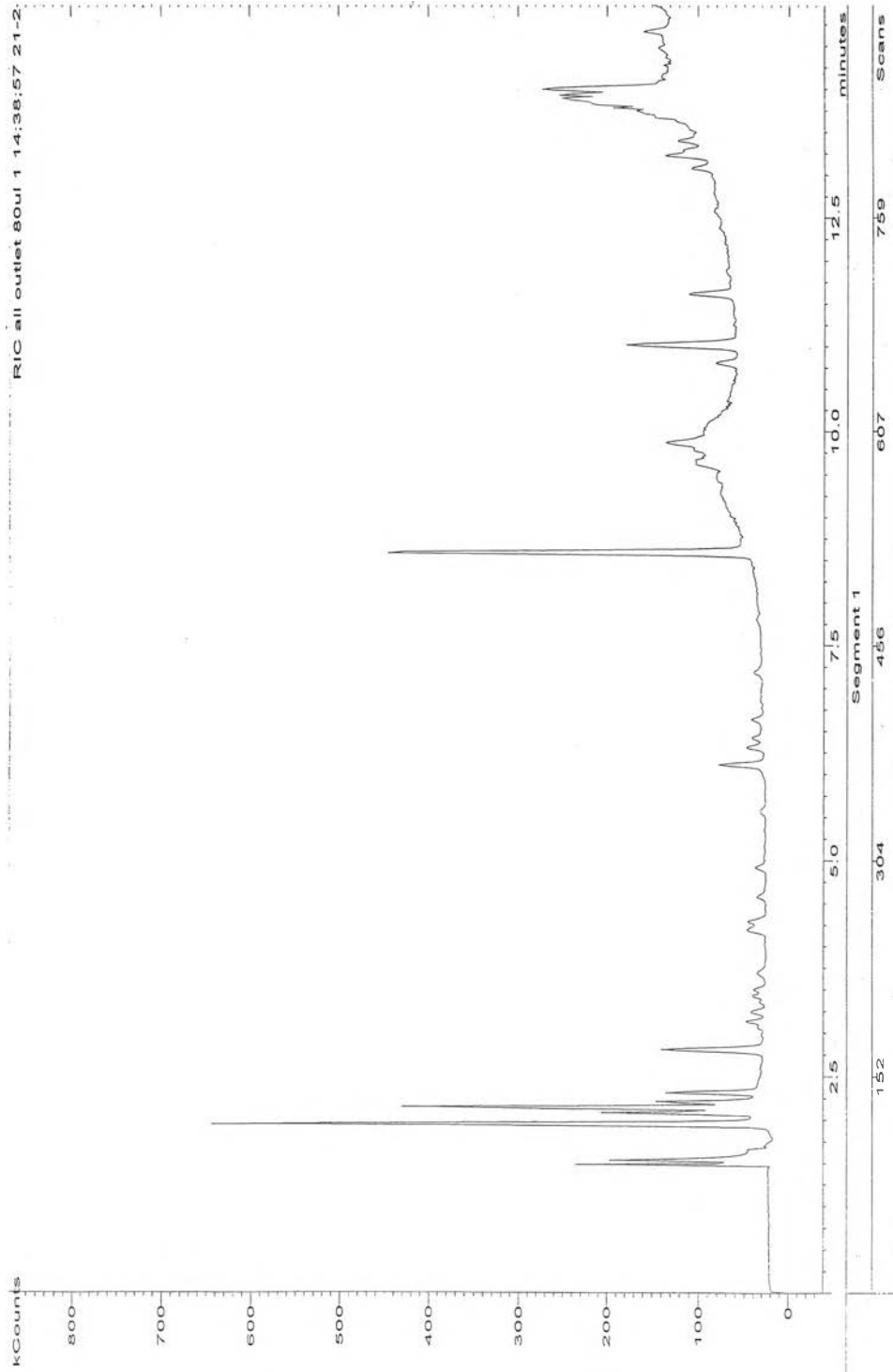
Totals : 717.54893

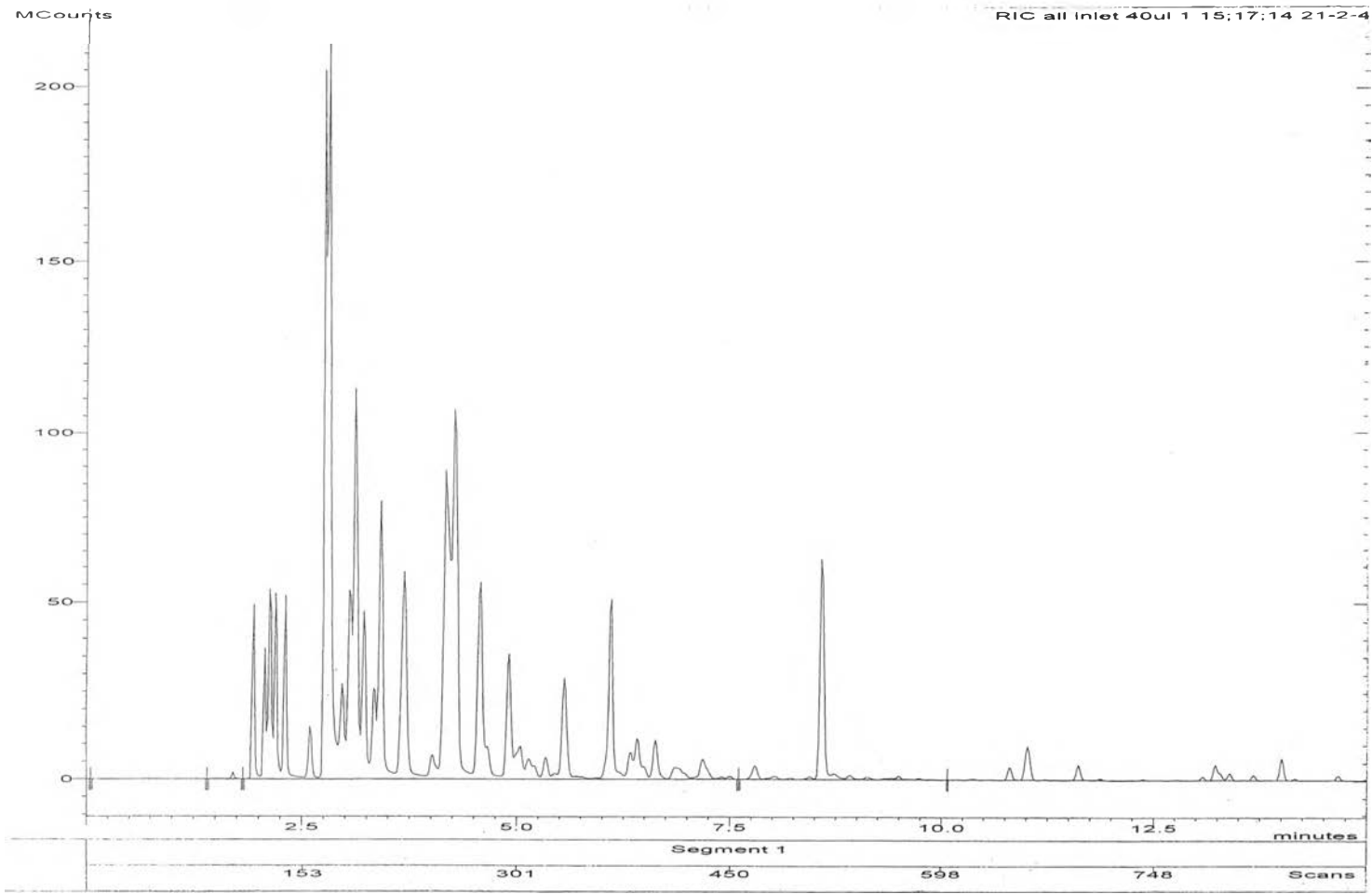
Results obtained with enhanced integrator!
 1 Warnings or Errors :

APPENDIX B

APPENDIX B

Chromatogram of GC/MS





Saturn Fit Search Hit List

Saturn Fit Search Hit List

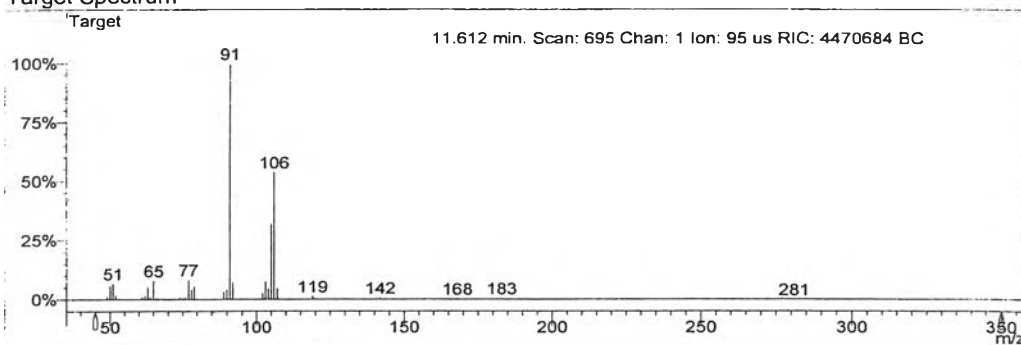
Saturn Fit Search Results

Hits Found: 25
Pre-Search Hits Found: 350

Saturn Fit Search Parameters

Threshold: 700
Target Ion Range: 45 - 350
Library MW Range: 45 - 250
Library Ion Range: 45 - 350 (Target Mass Range)
Local Normalization: On
Requested Pre-Search: 250
Requested Final Search: 25
Search 4 Libraries:
A. c:\saturnws\satlib\nist98m.lbr
B. c:\saturnws\satlib\nist98r.lbr
C. c:\saturnws\satlib\lbr_tr.lbr
D. c:\saturnws\satlib\lbr_tx.lbr

Target Spectrum



Spectrum from c:\... \cu oil\inlet 40ul 1 15;17;14 21-2-46.sms

Scan No: 695, Time: 11.612 minutes

No averaging. Background corrected.

Comment: 11.612 min. Scan: 695 Chan: 1 Ion: 95 us RIC: 4470684 BC

Pair Count: 67 MW: 0 Formula: None CAS No: None Acquired Range: 40 - 350

| | Purity | Fit | RFit | Entry # | MW. | Formula, CAS No., Name |
|-----|--------|-----|------|---------|-----|--|
| 1. | 928 | 979 | 979 | 9522 B | 106 | C8H10, 95-47-6, Benzene, 1,2-dimethyl- |
| 2. | 944 | 977 | 977 | 9508 B | 106 | C8H10, 108-38-3, Benzene, 1,3-dimethyl- |
| 3. | 895 | 975 | 975 | 9512 B | 106 | C8H10, 2175-91-9, 1,3-Cyclopentadiene, 5-(|
| 4. | 927 | 975 | 975 | 9510 B | 106 | C8H10, 108-38-3, Benzene, 1,3-dimethyl- |
| 5. | 927 | 975 | 975 | 9517 B | 106 | C8H10, 106-42-3, p-Xylene |
| 6. | 938 | 971 | 971 | 9514 B | 106 | C8H10, 106-42-3, p-Xylene |
| 7. | 936 | 970 | 970 | 9515 B | 106 | C8H10, 106-42-3, p-Xylene |
| 8. | 936 | 969 | 969 | 37716 A | 106 | C8H10, 106-42-3, p-Xylene |
| 9. | 936 | 969 | 969 | 9509 B | 106 | C8H10, 108-38-3, Benzene, 1,3-dimethyl- |
| 10. | 936 | 969 | 969 | 9518 B | 106 | C8H10, 106-42-3, p-Xylene |
| 11. | 935 | 969 | 969 | 9523 B | 106 | C8H10, 95-47-6, Benzene, 1,2-dimethyl- |
| 12. | 935 | 968 | 968 | 9511 B | 106 | C8H10, 108-38-3, Benzene, 1,3-dimethyl- |
| 13. | 934 | 968 | 968 | 9516 B | 106 | C8H10, 106-42-3, p-Xylene |
| 14. | 934 | 967 | 967 | 9524 B | 106 | C8H10, 95-47-6, Benzene, 1,2-dimethyl- |
| 15. | 932 | 966 | 966 | 37714 A | 106 | C8H10, 108-38-3, Benzene, 1,3-dimethyl- |
| 16. | 932 | 965 | 965 | 37719 A | 106 | C8H10, 95-47-6, Benzene, 1,2-dimethyl- |
| 17. | 928 | 961 | 961 | 9500 B | 106 | C8H10, 95-47-6, Benzene, 1,2-dimethyl- |
| 18. | 889 | 956 | 956 | 37691 A | 106 | C8H10, 2175-91-9, 1,3-Cyclopentadiene, 5-(|
| 19. | 918 | 951 | 951 | 9513 B | 106 | C8H10, 2175-91-9, 1,3-Cyclopentadiene, 5-(|
| 20. | 451 | 944 | 944 | 36724 A | 176 | C9H8N2O2, 16844-42-1, Sydnone, 3-(phenylme |
| 21. | 899 | 941 | 941 | 36861 A | 106 | C8H10, 2809-71-4, 2,4-Octadiyne |
| 22. | 881 | 940 | 940 | 9354 B | 106 | C8H10, 2809-71-4, 2,4-Octadiyne |
| 23. | 409 | 939 | 939 | 36763 A | 170 | C7H7Br, 5376-03-4, Cycloheptatrienylium, b |
| 24. | 897 | 939 | 939 | 36408 A | 106 | C8H10, None, 1,6-Heptadien-3-yne, 5-methyl |
| 25. | 891 | 937 | 937 | 37696 A | 106 | C8H10, 100-41-4, Ethylbenzene |

APPENDIX C

APPENDIX C

Daily calculation of VRU's ability for controlling gasoline vapor

Table C-1 Control Efficiency (CE%) of VRU at FPT

| Test | MTBE | Benzene | Toluene | Ethybenzene | o-Xylene | m-Xylene | Total VOC |
|------------------------------|--------|---------|---------|-------------|----------|----------|-----------|
| 21/1/03 test1 | 100.00 | 100.00 | 98.86 | 100.00 | 95.02 | 96.19 | 99.980 |
| test2 | 100.00 | 100.00 | 97.31 | na | na | na | 99.990 |
| 22/1/03 test1 | 100.00 | 99.91 | 99.44 | 100.00 | 100.00 | 100.00 | 99.991 |
| test2 | 100.00 | 100.00 | 99.74 | 100.00 | 100.00 | 100.00 | 99.996 |
| 23/1/03 test1 | 100.00 | 100.00 | 97.24 | na | na | na | 99.968 |
| test2 | 100.00 | 99.96 | 98.39 | na | na | 89.30 | 99.976 |
| 24/1/03 test1 | 100.00 | 100.00 | 100.00 | na | na | 100.00 | 99.984 |
| test2 | 100.00 | 100.00 | 98.71 | na | na | na | 99.996 |
| 25/1/03 test1 | 100.00 | 99.72 | 98.44 | na | na | na | 99.967 |
| test2 | 100.00 | 99.80 | 99.20 | na | na | 100.00 | 99.948 |
| 26/1/03 test1 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 99.989 |
| test2 | 100.00 | 100.00 | 100.00 | na | 100.00 | 100.00 | 99.999 |
| 27/1/03 test1 | 100.00 | 99.96 | na | 100.00 | 100.00 | 100.00 | 99.982 |
| test2 | 100.00 | 100.00 | na | 100.00 | 100.00 | 100.00 | 99.989 |
| 2/2/03 test1 | 100.00 | error | 100.00 | na | na | 100.00 | 99.978 |
| test2 | 100.00 | error | 100.00 | na | 100.00 | 100.00 | 99.974 |
| Average | 100.00 | 99.953 | 99.095 | 100.000 | 99.378 | 98.791 | 99.982 |
| Average HAP ^a CE% | 99.536 | | | | | | |

error Analysis error

na Not found compound both inlet&outlet

^a Benzene, Toluene, Ethylbenzene, m-Xylene, o-Xylene and Methyl tert-Butyl Ether

Table C-2 Control Efficiency (CE%) of VRU at SHELL

| Test | MTBE | Benzene | Toluene | Ethylbenzene | o-Xylene | m-Xylene | Total VOC |
|--|---------|-----------|-----------|--------------|----------|-----------|-----------|
| 1/12/02 test1 | 99.739 | 98.751 | na | 100 | na | 98.013 | 99.981 |
| test2 | 99.892 | 95.792 | na | na | 100 | na | 99.994 |
| 2/12/02 test1 | 100 | 98.089 | 98.08 | na | na | na | 99.961 |
| test2 | 97.778 | 99.437 | 100 | na | na | 100 | 99.986 |
| 3/12/02 test1 | 100 | 98.756 | na | na | na | na | 99.961 |
| test2 | 100 | 92.957 | na | na | na | na | 99.983 |
| 5/12/02 test1 | 100 | 99.979 | 99.798 | na | na | 100 | error |
| test2 | 100 | 99.939 | 100 | na | na | 100 | error |
| 8/12/02 test1 | 99.856 | 95.525 | na | na | na | na | 99.983 |
| test2 | 100 | 99.495 | na | na | na | na | 99.977 |
| 12/12/02 test1 | 97.014 | 92.943 | 94.483 | 100 | na | na | 99.952 |
| test2 | 100 | 97.896 | 97.179 | na | na | na | 99.953 |
| 13/2/03 test1 | 99.927 | 98.198 | 98.542 | 100 | na | 95.778 | 99.902 |
| test2 | 99.98 | 99.189 | 99.173 | 100 | 100 | 97.352 | 99.96 |
| 14/2/03 test1 | 99.461 | 92.692 | 87.142 | na | na | na | 99.768 |
| test2 | 100 | 96.78 | 96.386 | na | na | 88.443 | error |
| 16/2/03 test1 | 100 | 99.92 | 99.343 | 100 | 100 | 98.081 | 99.991 |
| test2 | 99.954 | 99.539 | 97.763 | 100 | 100 | 95.92 | 99.976 |
| Average | 99.6445 | 97.548721 | 97.324083 | 100 | 100 | 97.065222 | 99.9552 |
| Average HAP ^a CE% 98.597088 | | | | | | | |

error Analysis error

na Not found compound both inlet&outlet

^a Benzene, Toluene, Ethylbenzene, m-Xylene, o-Xylene and Methyl tert-Butyl Ether

BIOGRAPHY

Miss Chanpen Kanjnaprapan was born on February 7, 1974 in Satul, Thailand. She was graduated from the Occupational Health and Safety Department, Faculty of Public Health, Mahidol University in 1995.

She had worked at Sahaviriya Steel Industry (Public) Company as safety officer for two and haft years. In 1998, she had worked for Nestle Food (Thailand) as safety and environment supervisor for three and haft years. After that she started as a graduate student in the International Postgraduate Programs in Environmental Management, Inter-Department of Environmental Management, Chulalongkorn University in May 2001 and completed the program in May 2003.

