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## APPENDICES

### Appendix A Temperature Profiles

**Table A1** Pyrolysis conditions: Non-catalytic Pyrolysis

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 23.7 | 24.8 | 32 | 345.4 | 505.6 | 62 | 350.4 | 496.6 | 92 | 355.0 | 499.5 |
| 4 | 29.9 | 35.5 | 34 | 358.0 | 562.1 | 64 | 350.6 | 499.6 | 94 | | |
| 6 | 41.6 | 54.1 | 36 | 411.3 | 547.0 | 66 | | | 96 | 353.0 | 500.1 |
| 8 | 58.5 | 79.5 | 38 | 410.8 | 533.0 | 68 | 350.1 | 499.5 | 98 | 353.3 | 500.1 |
| 10 | 81.7 | 114.9 | 40 | 403.4 | 508.8 | 70 | 349.0 | 499.6 | 100 | 351.7 | 501.2 |
| 12 | 115.7 | 161.7 | 42 | 397.2 | 495.2 | 72 | 349.8 | 500.2 | 102 | 351.5 | 500.8 |
| 14 | 145.5 | 201.9 | 44 | 389.5 | 503.2 | 74 | 350.4 | 499.8 | 104 | 350.9 | 499.5 |
| 16 | 183.9 | 251.6 | 46 | 379.3 | 499.9 | 76 | 350.1 | 500.3 | 106 | 349.9 | 500.1 |
| 18 | 226.1 | 309.8 | 48 | 372.2 | 497.7 | 78 | 348.6 | 500.5 | 108 | 350.1 | 500.5 |
| 20 | 274.5 | 369.0 | 50 | 366.2 | 499.1 | 80 | 348.2 | 500.2 | 110 | 349.1 | 500.2 |
| 22 | 310.1 | 427.9 | 52 | 351.5 | 507.3 | 82 | 350.6 | 501.7 | 112 | 349.6 | 499.2 |
| 24 | 321.5 | 439.3 | 54 | 358.2 | 502.2 | 84 | 354.6 | 499.8 | 114 | 350.7 | 499.6 |
| 26 | 323.0 | 358.4 | 56 | 353.2 | 498.0 | 86 | 354.0 | 500.3 | 116 | 351.1 | 498.4 |
| 28 | 313.0 | 418.3 | 58 | 351.0 | 497.3 | 88 | 354.6 | 501.0 | 118 | 350.1 | 501 |
| 30 | 321.5 | 444.1 | 60 | 350.5 | 502.0 | 90 | 354.4 | 500.9 | 120 | 350.6 | 500.5 |

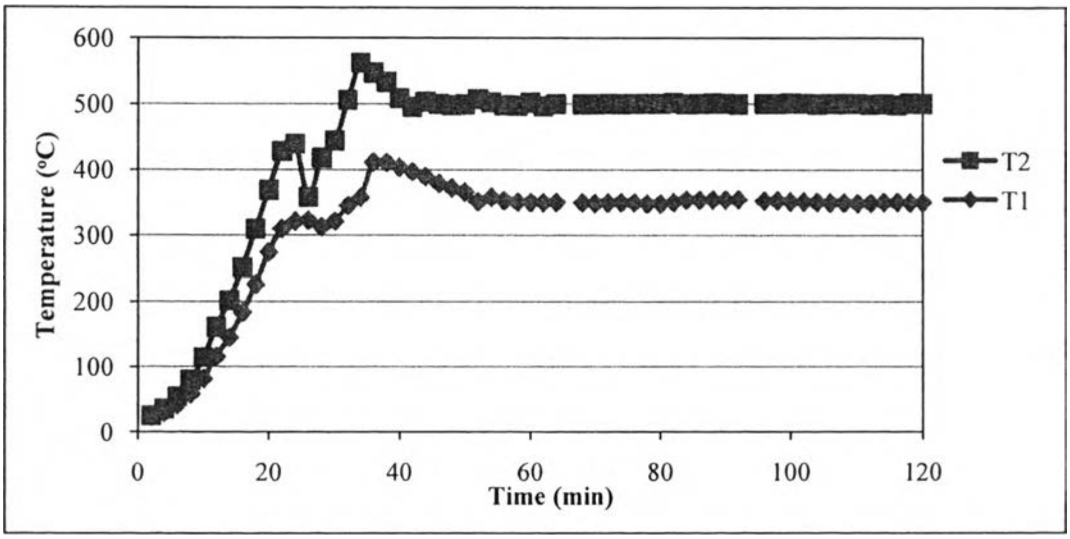



**Figure A1** Temperature profiles of non-catalytic pyrolysis case.

**Table A2** Pyrolysis conditions: 1%Pd/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 24.0 | 26.4 | 32 | 339.8 | 480.0 | 62 | 400.2 | 499.7 | 92 | 371.5 | 500.1 |
| 4 | 28.2 | 38.3 | 34 | 341.8 | 485.8 | 64 | 398.5 | 503.2 | 94 | 370.6 | 495.2 |
| 6 | 36.4 | 56.1 | 36 | 347.8 | 506.0 | 66 | 397.7 | 497.9 | 96 | 368.8 | 499.0 |
| 8 | 49.1 | 81.9 | 38 | 370.6 | 506.2 | 68 | 395.1 | 504.8 | 98 | 367.4 | 498.3 |
| 10 | 66.6 | 115.0 | 40 | 385.2 | 501.2 | 70 | 392.5 | 497.1 | 100 | 365.7 | 502.2 |
| 12 | 88.9 | 154.7 | 42 | 398.4 | 498.4 | 72 | 389.5 | 497.5 | 102 | 363.3 | 504.9 |
| 14 | 116.3 | 196.4 | 44 | 402.4 | 503.7 | 74 | 388.3 | 497.3 | 104 | 361.7 | 502.0 |
| 16 | 148.0 | 242.3 | 46 | 405.4 | 499.0 | 76 | 387.9 | 499.1 | 106 | 360.6 | 494.2 |
| 18 | 183.6 | 293.4 | 48 | 408.3 | 503.2 | 78 | 385.1 | 499.9 | 108 | 359.1 | 495.6 |
| 20 | 220.0 | 345.0 | 50 | 408.2 | 502.7 | 80 | 381.9 | 501.5 | 110 | 357.2 | 499.3 |
| 22 | 264.0 | 414.1 | 52 | 408.7 | 499.3 | 82 | 380.5 | 498.7 | 112 | 356.9 | 498.5 |
| 24 | 309.0 | 440.1 | 54 | 407.5 | 501.3 | 84 | 378.9 | 503.0 | 114 | 354.8 | 499.0 |
| 26 | 329.4 | 481.0 | 56 | 406.3 | 499.7 | 86 | 376.2 | 499.3 | 116 | 353.3 | 499.3 |
| 28 | 330.2 | 490.9 | 58 | 403.4 | 504.2 | 88 | 376.2 | 503.9 | 118 | 351.6 | 499.5 |
| 30 | 330.5 | 489.0 | 60 | 402.9 | 498.2 | 90 | 373.7 | 504.5 | 120 | 350.3 | 500.8 |

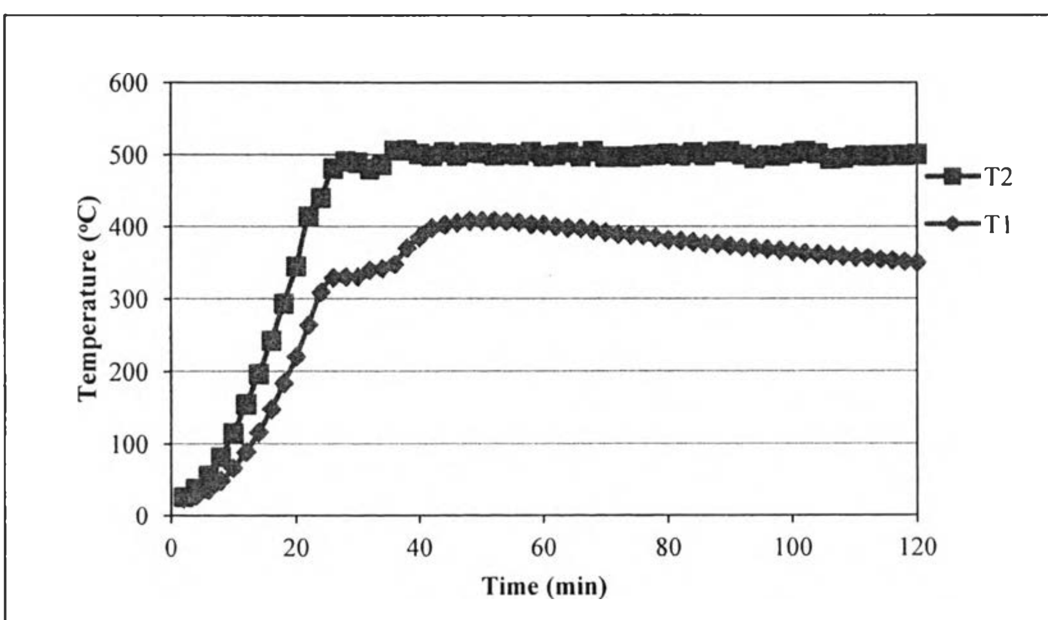



**Figure A2** Temperature profiles of waste tire pyrolysis with using 1% Pd/HBeta catalyst.

**Table A3** Pyrolysis conditions: 5%Ni/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 26.1 | 28.9 | 32 | 343.2 | 483.8 | 62 | 430.9 | 500.9 | 92 | 385.8 | 499.8 |
| 4 | 31.3 | 40.7 | 34 | 387.4 | 495.6 | 64 | 427.6 | 498.4 | 94 | 382.9 | 500.3 |
| 6 | 40.4 | 58.5 | 36 | 403.9 | 510.6 | 66 | 424.5 | 499.3 | 96 | 380.1 | 499.5 |
| 8 | 56.4 | 85.6 | 38 | 426.0 | 512.9 | 68 | 420.7 | 499.4 | 98 | 377.4 | 499.6 |
| 10 | 79.3 | 120.1 | 40 | 440.9 | 510.9 | 70 | 417.2 | 500.4 | 100 | 375.4 | 500.0 |
| 12 | 105.9 | 160.6 | 42 | 447.4 | 506.3 | 72 | 414.3 | 499.8 | 102 | 373.4 | 499.8 |
| 14 | 134.7 | 205.1 | 44 | 452.0 | 501.4 | 74 | 411.0 | 499.4 | 104 | 371.2 | 499.8 |
| 16 | 166.5 | 256.3 | 46 | 450.3 | 504.4 | 76 | 408.2 | 499.8 | 106 | 368.6 | 500.1 |
| 18 | 201.5 | 307.7 | 48 | 452.9 | 502.8 | 78 | 405.4 | 498.3 | 108 | 366.3 | 499.9 |
| 20 | 236.0 | 361.7 | 50 | 450.8 | 496.1 | 80 | 402.7 | 500.1 | 110 | 364.4 | 500.1 |
| 22 | 285.8 | 411.7 | 52 | 448.6 | 497.2 | 82 | 399.4 | 500.3 | 112 | 362.5 | 499.8 |
| 24 | 334.7 | 446.5 | 54 | 442.0 | 499.3 | 84 | 395.2 | 500.0 | 114 | 360.8 | 499.8 |
| 26 | 344.0 | 474.3 | 56 | 441.7 | 499.2 | 86 | 394.2 | 499.9 | 116 | 358.3 | 500.0 |
| 28 | 294.0 | 428.3 | 58 | 437.3 | 499.3 | 88 | 390.9 | 499.5 | 118 | 357.4 | 500.0 |
| 30 | 311.2 | 483.0 | 60 | 434.4 | 499.9 | 90 | 388.3 | 500.4 | 120 | 355.8 | 498.9 |

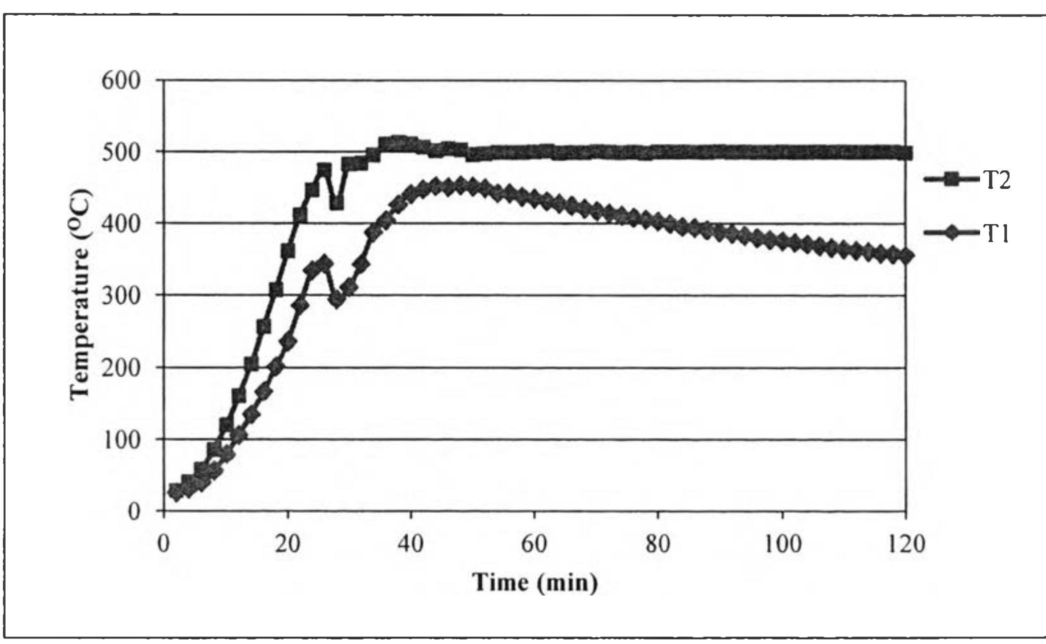



**Figure A3** Temperature profiles of waste tire pyrolysis with using 5% Ni/HBeta catalyst.

**Table A4** Pyrolysis conditions: 10%Ni/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 26.8 | 28.9 | 32 | 340.1 | 539.2 | 62 | 369.6 | 499.3 | 92 | 352.4 | 500.5 |
| 4 | 33.3 | 42.2 | 34 | 368.7 | 521.1 | 64 | 368.6 | 500.8 | 94 | 351.3 | 500.0 |
| 6 | 44.5 | 61.3 | 36 | 367.7 | 511.3 | 66 | 367.2 | 499.8 | 96 | 350.4 | 500.1 |
| 8 | 61.9 | 89.7 | 38 | 359.7 | 500.4 | 68 | 365.6 | 500.2 | 98 | 349.5 | 501.1 |
| 10 | 86.1 | 123.1 | 40 | 357.5 | 496.6 | 70 | 364.6 | 500.3 | 100 | 349.9 | 500.3 |
| 12 | 113.9 | 165.3 | 42 | 358.7 | 501.4 | 72 | 363.8 | 500.0 | 102 | 353.8 | 499.9 |
| 14 | 148.3 | 216.5 | 44 | 359.8 | 500.7 | 74 | 362.6 | 500.3 | 104 | 357.6 | 498.7 |
| 16 | 175.7 | 263.7 | 46 | 361.5 | 501.7 | 76 | 361.4 | 499.9 | 106 | 357.2 | 499.2 |
| 18 | 211.8 | 315.6 | 48 | 367.3 | 503.0 | 78 | 360.3 | 498.7 | 108 | 352.9 | 498.8 |
| 20 | 249.5 | 372.1 | 50 | 368.3 | 494.5 | 80 | 360.5 | 500.6 | 110 | 351.8 | 501.4 |
| 22 | 304.8 | 419.8 | 52 | 369.5 | 495.3 | 82 | 359.5 | 500.2 | 112 | 351.0 | 502.3 |
| 24 | 331.1 | 459.8 | 54 | 370.0 | 498.5 | 84 | 358.1 | 500.1 | 114 | 350.6 | 501.8 |
| 26 | 332.0 | 399.5 | 56 | 370.6 | 500.7 | 86 | 356.8 | 500.0 | 116 | 348.0 | 502.1 |
| 28 | 326.4 | 478.0 | 58 | 370.1 | 499.2 | 88 | 355.2 | 499.7 | 118 | 347.8 | 500.2 |
| 30 | 309.9 | 543.2 | 60 | 368.8 | 500.9 | 90 | 354.2 | 499.8 | 120 | 350.1 | 499.3 |

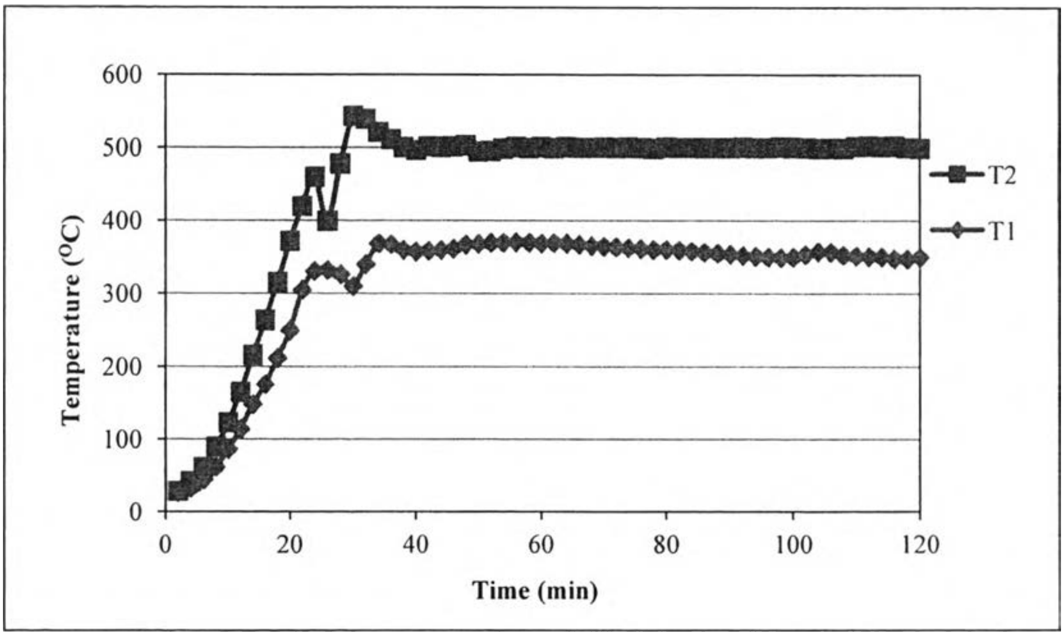



**Figure A4** Temperature profiles of waste tire pyrolysis with using 10% Ni/HBeta catalyst.

**Table A5** Pyrolysis conditions: 20%Ni/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 24.2 | 24.5 | 32 | 355.3 | 499.1 | 62 | 351.3 | 500.0 | 92 | 358.3 | 499.1 |
| 4 | 29.3 | 35.5 | 34 | 338.9 | 507.0 | 64 | 341.9 | 505.3 | 94 | 353.8 | 500.4 |
| 6 | 40.4 | 58.7 | 36 | 353.2 | 504.3 | 66 | 341.1 | 501.2 | 96 | 348.3 | 499.7 |
| 8 | 55.9 | 83.5 | 38 | 371.2 | 501.7 | 68 | 342.7 | 500.1 | 98 | 345.6 | 502.4 |
| 10 | 73.0 | 108.2 | 40 | 380.4 | 503.7 | 70 | 350.4 | 501.0 | 100 | 354.3 | 500.3 |
| 12 | 99.0 | 149.2 | 42 | 382.6 | 504.6 | 72 | 352.1 | 501.2 | 102 | 357.6 | 498.7 |
| 14 | 128.0 | 199.4 | 44 | 384.2 | 500.3 | 74 | 353.0 | 494.6 | 104 | 358.4 | 500.8 |
| 16 | 160.4 | 244.0 | 46 | 404.5 | 495.6 | 76 | 348.0 | 499.6 | 106 | 361.4 | 495.8 |
| 18 | 195.8 | 297.5 | 48 | 398.4 | 493.9 | 78 | 345.3 | 500.4 | 108 | 360.0 | 497.7 |
| 20 | 236.0 | 350.1 | 50 | 392.7 | 499.5 | 80 | 342.2 | 499.9 | 110 | 358.6 | 500.5 |
| 22 | 274.0 | 413.2 | 52 | 386.9 | 498.6 | 82 | 342.7 | 500.2 | 112 | 352.2 | 500.1 |
| 24 | 311.5 | 441.5 | 54 | 380.8 | 499.8 | 84 | 352.4 | 505.9 | 114 | 346.1 | 499.9 |
| 26 | 334.5 | 474.9 | 56 | 370.4 | 501.0 | 86 | 359.6 | 500.1 | 116 | 344.3 | 500.2 |
| 28 | 343.8 | 480.3 | 58 | 365.5 | 500.3 | 88 | 360.6 | 496.2 | 118 | 345.0 | 501.3 |
| 30 | 342.9 | 495.6 | 60 | 358.7 | 501.5 | 90 | 354.5 | 498.4 | 120 | 350.8 | 505.0 |

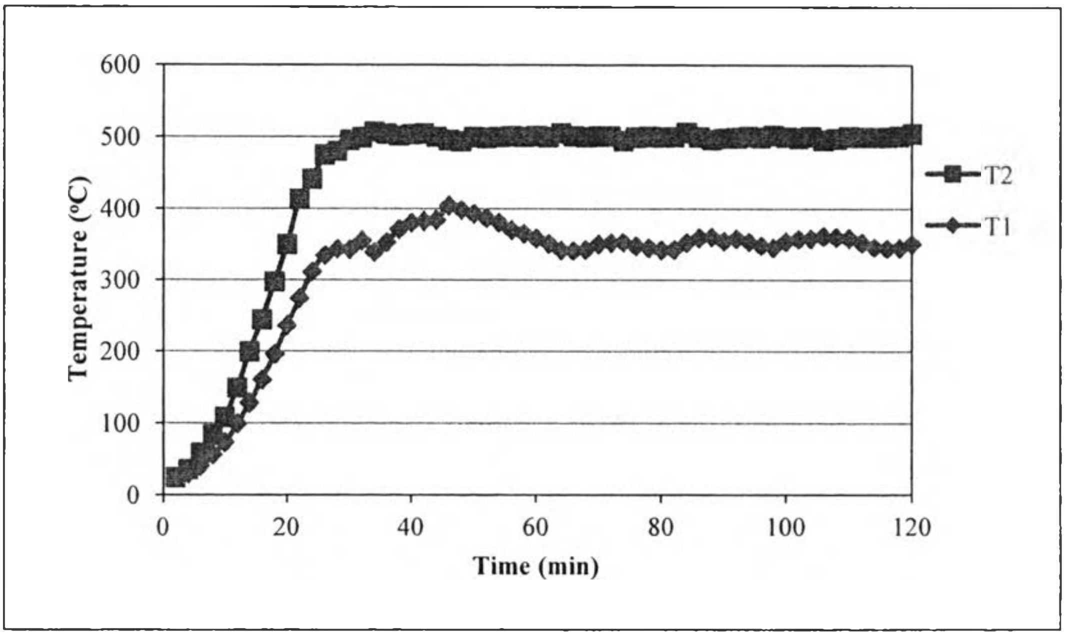



**Figure A5** Temperature profiles of waste tire pyrolysis with using 20% Ni/HBeta catalyst.

**Table A6** Pyrolysis conditions: HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 26.3 | 29.9 | 32 | 344.0 | 501.2 | 62 | 366.3 | 499.9 | 92 | 349.0 | 500.1 |
| 4 | 31.8 | 43.0 | 34 | 354.6 | 499.0 | 64 | 356.8 | 500.6 | 94 | 349.9 | 501.6 |
| 6 | 45.8 | 70.9 | 36 | 361.8 | 500.8 | 66 | 349.6 | 500.4 | 96 | 350.1 | 500.1 |
| 8 | 59.2 | 98.7 | 38 | 370.5 | 499.6 | 68 | 349.2 | 503.8 | 98 | 349.7 | 501.0 |
| 10 | 82.1 | 141.2 | 40 | 377.8 | 499.3 | 70 | 343.0 | 502.3 | 100 | 348.4 | 499.5 |
| 12 | 107.0 | 186.2 | 42 | 374.5 | 500.3 | 72 | 342.5 | 498.5 | 102 | 351.3 | 500.7 |
| 14 | 151.6 | 256.2 | 44 | 375.7 | 500.1 | 74 | 342.0 | 500.0 | 104 | 352.8 | 498.1 |
| 16 | 175.6 | 289.7 | 46 | 377.7 | 500.1 | 76 | 341.2 | 500.3 | 106 | 351.4 | 498.4 |
| 18 | 215.0 | 360.7 | 48 | 379.0 | 500.1 | 78 | 341.3 | 500.7 | 108 | 355.3 | 500.8 |
| 20 | 262.8 | 400.1 | 50 | 379.9 | 502.0 | 80 | 341.6 | 501.2 | 110 | 353.3 | 500.6 |
| 22 | 271.5 | 452.2 | 52 | 379.4 | 500.1 | 82 | 341.2 | 499.5 | 112 | 346.1 | 504.4 |
| 24 | 286.9 | 475.8 | 54 | 379.5 | 500.7 | 84 | 341.7 | 500.0 | 114 | 350.9 | 503.7 |
| 26 | 296.4 | 502.5 | 56 | 380.4 | 499.7 | 86 | 346.9 | 500.1 | 116 | 353.6 | 499.1 |
| 28 | 309.8 | 500.7 | 58 | 379.4 | 498.3 | 88 | 350.4 | 500.7 | 118 | 353.8 | 500.3 |
| 30 | 326.0 | 499.3 | 60 | 373.0 | 499.1 | 90 | 350.3 | 500.9 | 120 | 350.4 | 498.8 |

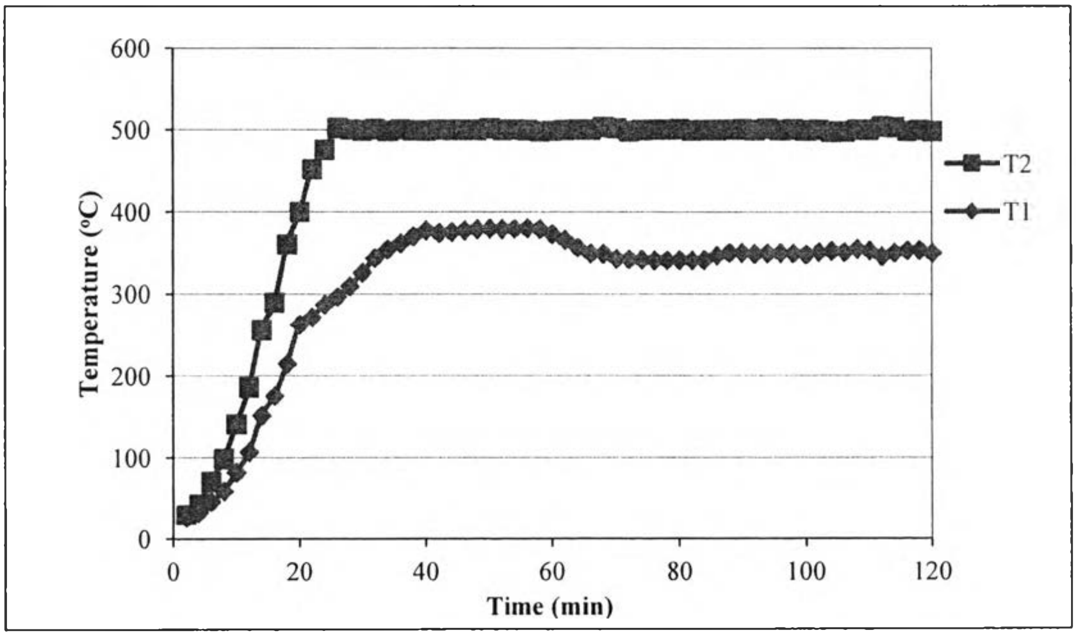



**Figure A6** Temperature profiles of waste tire pyrolysis with using HMOR catalyst.

**Table A7** Pyrolysis conditions: 1%Pd/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 24.4 | 24.8 | 32 | 370.5 | 533.2 | 62 | 359.0 | 500.1 | 92 | 352.9 | 500.8 |
| 4 | 29.5 | 36.5 | 34 | 390.4 | 526.7 | 64 | 359.6 | 499.1 | 94 | 352.0 | 500.8 |
| 6 | 40.4 | 56.9 | 36 | 396.7 | 523.5 | 66 | 359.9 | 498.4 | 96 | 351.2 | 500.7 |
| 8 | 60.9 | 90.4 | 38 | 408.5 | 517.7 | 68 | 358.0 | 500.0 | 98 | 350.0 | 500.3 |
| 10 | 83.4 | 124.5 | 40 | 408.8 | 510.6 | 70 | 358.7 | 499.2 | 100 | 349.7 | 499.6 |
| 12 | 118.4 | 173.4 | 42 | 399.1 | 498.7 | 72 | 359.2 | 500.0 | 102 | 347.1 | 500.9 |
| 14 | 149.6 | 219.6 | 44 | 396.1 | 504.1 | 74 | 358.2 | 498.7 | 104 | 346.6 | 500.3 |
| 16 | 187.7 | 280.5 | 46 | 385.5 | 497.8 | 76 | 358.4 | 499.9 | 106 | 345.8 | 498.4 |
| 18 | 220.4 | 327.8 | 48 | 378.8 | 502.8 | 78 | 358.0 | 500.2 | 108 | 350.3 | 501.3 |
| 20 | 264.1 | 384.5 | 50 | 368.9 | 497.7 | 80 | 357.7 | 502.4 | 110 | 350.6 | 499.6 |
| 22 | 298.1 | 436.2 | 52 | 353.1 | 499.4 | 82 | 356.3 | 499.6 | 112 | 352.1 | 503.9 |
| 24 | 317.1 | 466.2 | 54 | 353.7 | 497.2 | 84 | 355.9 | 499.2 | 114 | 354.6 | 498.8 |
| 26 | 320.9 | 501.5 | 56 | 359.2 | 497.4 | 86 | 355.2 | 499.6 | 116 | 356.6 | 502.4 |
| 28 | 333.4 | 490.7 | 58 | 356.0 | 501.8 | 88 | 354.8 | 499.5 | 118 | 356.8 | 500.7 |
| 30 | 336.5 | 531.7 | 60 | 358.2 | 500.2 | 90 | 354.0 | 499.7 | 120 | 356.5 | 499.8 |

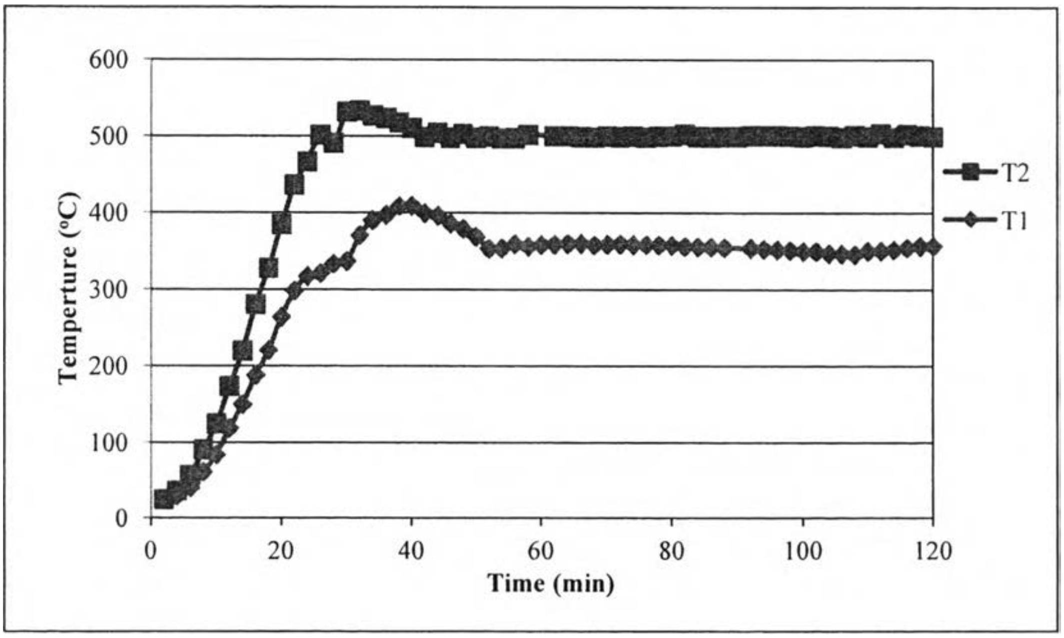



**Figure A7** Temperature profiles of waste tire pyrolysis with using 1%Pd/HMOR catalyst.

**Table A8** Pyrolysis conditions: 5%Ni/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 24.8 | 24.4 | 32 | 337.9 | 532.2 | 62 | 357.9 | 498.7 | 92 | 353.7 | 500.1 |
| 4 | 29.9 | 34.6 | 34 | 349.1 | 518.4 | 64 | 358.4 | 500.2 | 94 | 355.3 | 498.9 |
| 6 | 39.3 | 50.9 | 36 | 355.3 | 506.9 | 66 | 358.5 | 499.8 | 96 | 355.4 | 500.7 |
| 8 | 54.0 | 74.8 | 38 | 361.5 | 492.4 | 68 | 357.6 | 501.0 | 98 | 355.8 | 499.4 |
| 10 | 77.0 | 108.5 | 40 | 359.8 | 478.7 | 70 | 354.4 | 498.2 | 100 | 350.5 | 499.8 |
| 12 | 104.1 | 149.6 | 42 | 357.2 | 486.9 | 72 | 356.6 | 501.3 | 102 | 348.4 | 502.3 |
| 14 | 134.4 | 195.5 | 44 | 353.5 | 505.1 | 74 | 356.1 | 500.7 | 104 | 351.2 | 499.0 |
| 16 | 168.8 | 249.0 | 46 | 350.5 | 497.8 | 76 | 355.4 | 499.3 | 106 | 355.3 | 500.9 |
| 18 | 204.9 | 301.8 | 48 | 345.1 | 501.0 | 78 | 355.0 | 502.2 | 108 | 356.7 | 500.8 |
| 20 | 250.4 | 360.7 | 50 | 351.9 | 501.2 | 80 | 354.0 | 499.2 | 110 | 356.3 | 499.4 |
| 22 | 281.9 | 419.1 | 52 | | | 82 | 353.9 | 501.2 | 112 | 357.2 | 501.5 |
| 24 | 273.1 | 443.7 | 54 | 358.1 | 499.0 | 84 | 352.5 | 500.9 | 114 | 357.5 | 498.8 |
| 26 | 304.1 | 483.4 | 56 | 360.8 | 500.5 | 86 | 352.1 | 499.7 | 116 | 352.4 | 499.5 |
| 28 | 319.2 | 457.8 | 58 | 359.2 | 500.8 | 88 | 350.9 | 499.1 | 118 | 350.0 | 500.0 |
| 30 | 313.4 | 537.9 | 60 | 360.5 | 500.4 | 90 | 350.0 | 499.5 | 120 | 346.9 | 500.2 |

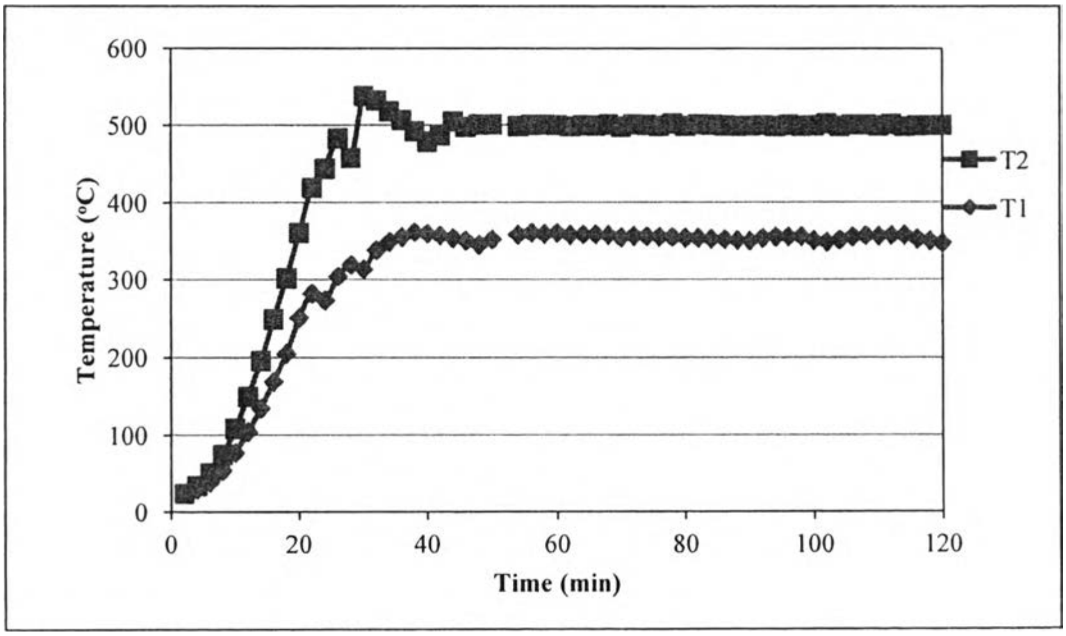



**Figure A8** Temperature profiles of waste tire pyrolysis with using 5%Ni/HMOR catalyst.

**Table A9** Pyrolysis conditions: 10%Ni/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 26.7 | 29.4 | 32 | 411.0 | 539.6 | 62 | 417.1 | 493.8 | 92 | 348.4 | 499.1 |
| 4 | 32.7 | 38.8 | 34 | | | 64 | 412.0 | 496.0 | 94 | 351.7 | 503.0 |
| 6 | 43.3 | 56.6 | 36 | 427.0 | 537.5 | 66 | | | 96 | 352.8 | 500.4 |
| 8 | 63.0 | 86.2 | 38 | 434.0 | 533.3 | 68 | 404.7 | 499.4 | 98 | 352.7 | 501.0 |
| 10 | 87.8 | 119.8 | 40 | 442.5 | 525.0 | 70 | 400.8 | 500.4 | 100 | 350.2 | 498.7 |
| 12 | 115.9 | 161.2 | 42 | 445.7 | 520.2 | 72 | 393.9 | 501.8 | 102 | 351.3 | 501.9 |
| 14 | 142.2 | 197.5 | 44 | 442.7 | 514.8 | 74 | 385.7 | 499.7 | 104 | 350.8 | 500.7 |
| 16 | 184.6 | 259.2 | 46 | 443.0 | 511.9 | 76 | 382.9 | 499.3 | 106 | 350.5 | 499.9 |
| 18 | 222.2 | 312.8 | 48 | 441.5 | 503.9 | 78 | 378.7 | 497.3 | 108 | 355.8 | 500.7 |
| 20 | 267.3 | 371.9 | 50 | 439.4 | 495.2 | 80 | 372.9 | 499.1 | 110 | 357.7 | 501.1 |
| 22 | 296.0 | 427.8 | 52 | 436.6 | 489.7 | 82 | 368.0 | 500.0 | 112 | 356.7 | 499.7 |
| 24 | 332.1 | 453.0 | 54 | 433.1 | 504.9 | 84 | 364.1 | 500.8 | 114 | 355.8 | 500.1 |
| 26 | 337.0 | 486.5 | 56 | 430.7 | 503.1 | 86 | 360.6 | 500.1 | 116 | 354.3 | 499.5 |
| 28 | 345.0 | 512.6 | 58 | 427.3 | 497.7 | 88 | 356.8 | 501.0 | 118 | 352.3 | 500.4 |
| 30 | 349.7 | 537.5 | 60 | 423.1 | 503.7 | 90 | 351.5 | 500.2 | 120 | 350.8 | 499.2 |

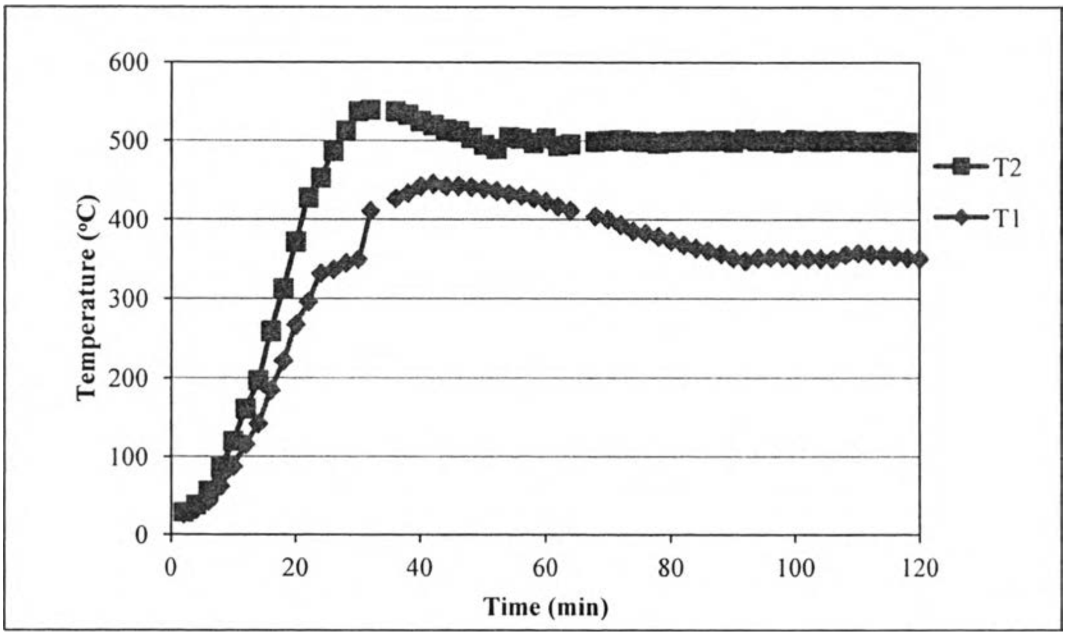



**Figure A9** Temperature profiles of waste tire pyrolysis with using 10%Ni/HMOR catalyst.

**Table A10** Pyrolysis conditions: 20%Ni/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 23.5 | 24.0 | 32 | 360.5 | 523.7 | 62 | 384.6 | 498.6 | 92 | 366.7 | 496.5 |
| 4 | 28.0 | 36.3 | 34 | 380.0 | 519.2 | 64 | 383.8 | 499.5 | 94 | 366.3 | 497.8 |
| 6 | 41.5 | 63.0 | 36 | 386.5 | 509.9 | 66 | 383.0 | 500.8 | 96 | 364.9 | 502.0 |
| 8 | 63.7 | 99.2 | 38 | 391.4 | 502.9 | 68 | 382.1 | 501.3 | 98 | 346.9 | 500.6 |
| 10 | 86.6 | 130.1 | 40 | 391.3 | 499.9 | 70 | 381.1 | 502.8 | 100 | 359.5 | 502.6 |
| 12 | 113.6 | 173.7 | 42 | 392.3 | 504.3 | 72 | 380.0 | 499.0 | 102 | 356.0 | 502.1 |
| 14 | 145.8 | 224.0 | 44 | 392.7 | 493.0 | 74 | 377.9 | 499.5 | 104 | 354.2 | 499.9 |
| 16 | 190.3 | 295.6 | 46 | 393.3 | 483.3 | 76 | 377.1 | 500.6 | 106 | 350.7 | 498.7 |
| 18 | 220.7 | 336.5 | 48 | 392.2 | 476.8 | 78 | 375.2 | 500.4 | 108 | 345.3 | 503.3 |
| 20 | 278.7 | 404.3 | 50 | 390.0 | 488.3 | 80 | 374.2 | 500.9 | 110 | 345.1 | 499.9 |
| 22 | 318.0 | 450.7 | 52 | 388.5 | 502.9 | 82 | 372.3 | 499.5 | 112 | 348.7 | 499.3 |
| 24 | 328.6 | 485.5 | 54 | 388.1 | 503.3 | 84 | 371.1 | 500.9 | 114 | 350.4 | 498.7 |
| 26 | 345.4 | 498.2 | 56 | 387.0 | 502.2 | 86 | 370.5 | 499.1 | 116 | 351.2 | 501.9 |
| 28 | 330.1 | 510.7 | 58 | 386.6 | 494.7 | 88 | 368.3 | 499.6 | 118 | 353.7 | 501.0 |
| 30 | 343.2 | 531.4 | 60 | 385.2 | 498.4 | 90 | 367.3 | 500.9 | 120 | 359.5 | 500.2 |

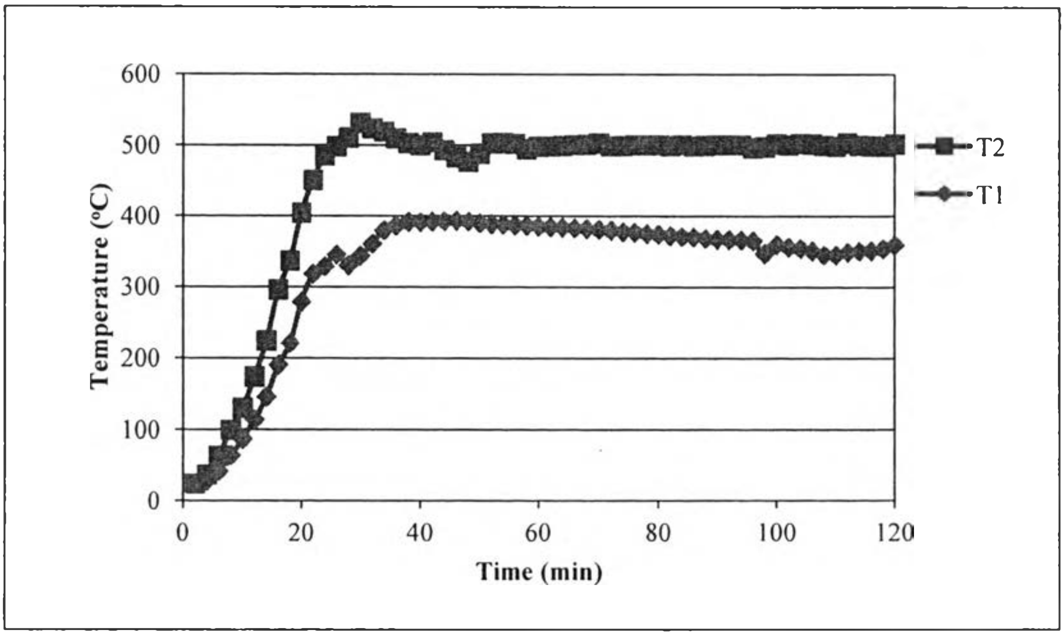



**Figure A10** Temperature profiles of waste tire pyrolysis with using 20%Ni/HMOR catalyst.

**Table A11** Pyrolysis conditions: 1%Ru/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 28.0 | 26.8 | 32 | 366.6 | 500.0 | 62 | 355.6 | 501.3 | 92 | 340.5 | 500.7 |
| 4 | 33.9 | 39.7 | 34 | 379.3 | 500.9 | 64 | 367.0 | 502.4 | 94 | 343.7 | 499.9 |
| 6 | 50.5 | 68.8 | 36 | 370.2 | 499.8 | 66 | 360.4 | 500.2 | 96 | 345.5 | 501.4 |
| 8 | 66.5 | 94.8 | 38 | 364.1 | 498.6 | 68 | 362.5 | 499.9 | 98 | 349.3 | 500.2 |
| 10 | 90.7 | 132.7 | 40 | 351.3 | 492.8 | 70 | 367.2 | 500.8 | 100 | 349.9 | 502.3 |
| 12 | 119.6 | 178.3 | 42 | 338.7 | 499.8 | 72 | 366.8 | 500.3 | 102 | 351.2 | 498.8 |
| 14 | 170.1 | 254.6 | 44 | 337.4 | 500.1 | 74 | 366.0 | 499.9 | 104 | 352.3 | 497.0 |
| 16 | 193.2 | 302.0 | 46 | 345.4 | 500.3 | 76 | 365.5 | 501.1 | 106 | 352.4 | 498.8 |
| 18 | 224.3 | 352.4 | 48 | 351.5 | 501.6 | 78 | 364.7 | 498.8 | 108 | 353.2 | 499.8 |
| 20 | 272.1 | 423.9 | 50 | 358.3 | 500.8 | 80 | 362.9 | 501.8 | 110 | 353.7 | 501.3 |
| 22 | 325.0 | 457.7 | 52 | 358.2 | 493.2 | 82 | 353.1 | 493.5 | 112 | 352.8 | 499.7 |
| 24 | 344.6 | 479.5 | 54 | 349.5 | 498.6 | 84 | 339.1 | 499.7 | 114 | 352.6 | 500.3 |
| 26 | 309.6 | 520.7 | 56 | 342.6 | 499.1 | 86 | 330.0 | 503.0 | 116 | 351.5 | 501.4 |
| 28 | 327.9 | 515.8 | 58 | 340.4 | 500.7 | 88 | 334.8 | 500.8 | 118 | 349.9 | 500.0 |
| 30 | 352.4 | 505.4 | 60 | 342.9 | 504.4 | 90 | 336.3 | 501.7 | 120 | 348.8 | 497.4 |

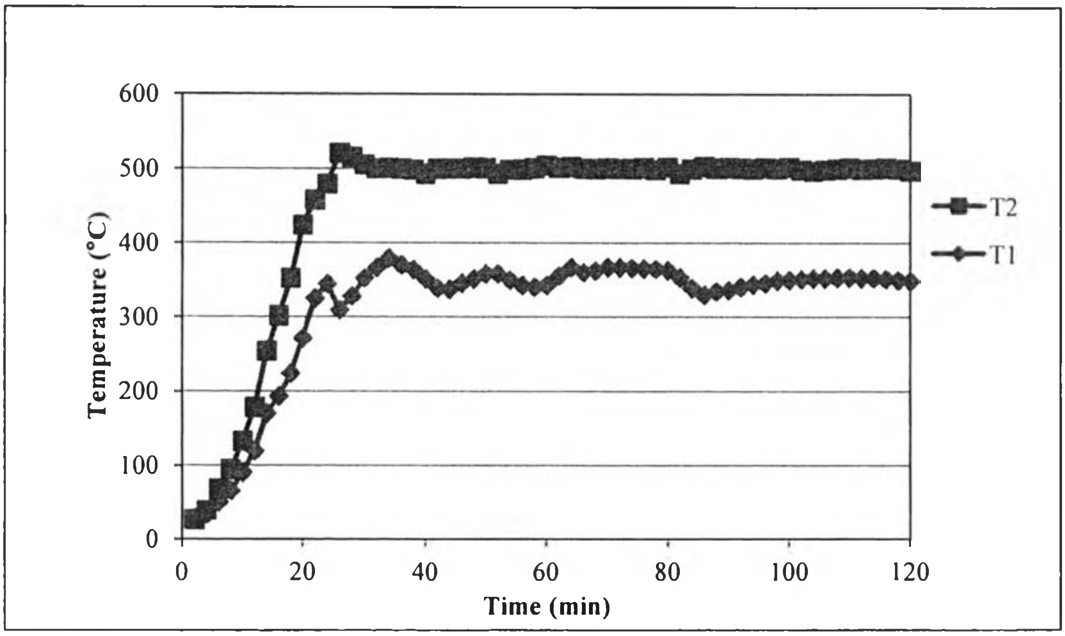



**Figure A11** Temperature profiles of waste tire pyrolysis with using 1%Ru/HBeta catalyst.

**Table A12** Pyrolysis conditions: 5%Fe/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 23.9 | 25.6 | 32 | 362.5 | 500.5 | 62 | 386.9 | 500.1 | 92 | 368.4 | 500.8 |
| 4 | 32.4 | 50.2 | 34 | 369.5 | 505.2 | 64 | 386.1 | 500.5 | 94 | 367.2 | 499.3 |
| 6 | 41.6 | 62.3 | 36 | 372.9 | 503.9 | 66 | 384.7 | 499.8 | 96 | 365.8 | 500.3 |
| 8 | 58.9 | 91.9 | 38 | 382.1 | 496.6 | 68 | 384.1 | 501.4 | 98 | 364.8 | 499.7 |
| 10 | 84.7 | 134.1 | 40 | 387.7 | 497.7 | 70 | 382.4 | 499.9 | 100 | 363.8 | 499.8 |
| 12 | 113.5 | 182.9 | 42 | 387.5 | 499.2 | 72 | 380.7 | 498.4 | 102 | 362.7 | 499.6 |
| 14 | 146.1 | 233.1 | 44 | 389.1 | 500.0 | 74 | 379.5 | 500.5 | 104 | 361.1 | 500.0 |
| 16 | 182.1 | 300.4 | 46 | 390.9 | 500.7 | 76 | 378.5 | 500.1 | 106 | 360.4 | 500.0 |
| 18 | 227.5 | 353.2 | 48 | 389.7 | 500.2 | 78 | 376.7 | 500.3 | 108 | 358.6 | 501.3 |
| 20 | 266.7 | 401.8 | 50 | 389.6 | 500.8 | 80 | 374.8 | 499.5 | 110 | 358.1 | 499.2 |
| 22 | 328.7 | 451.0 | 52 | 391.0 | 500.9 | 82 | 373.8 | 501.6 | 112 | 356.8 | 498.6 |
| 24 | 357.1 | 487.1 | 54 | 390.4 | 499.9 | 84 | 372.8 | 499.8 | 114 | 356.2 | 501.4 |
| 26 | 363.2 | 513.2 | 56 | 390.3 | 500.9 | 86 | 371.9 | 497.9 | 116 | 355.2 | 501.2 |
| 28 | 328.1 | 508.1 | 58 | 387.8 | 500.1 | 88 | 370.2 | 501.1 | 118 | 354.3 | 502.1 |
| 30 | 334.1 | 500.4 | 60 | 387.6 | 499.6 | 90 | 370.1 | 499.6 | 120 | 354.0 | 496.4 |

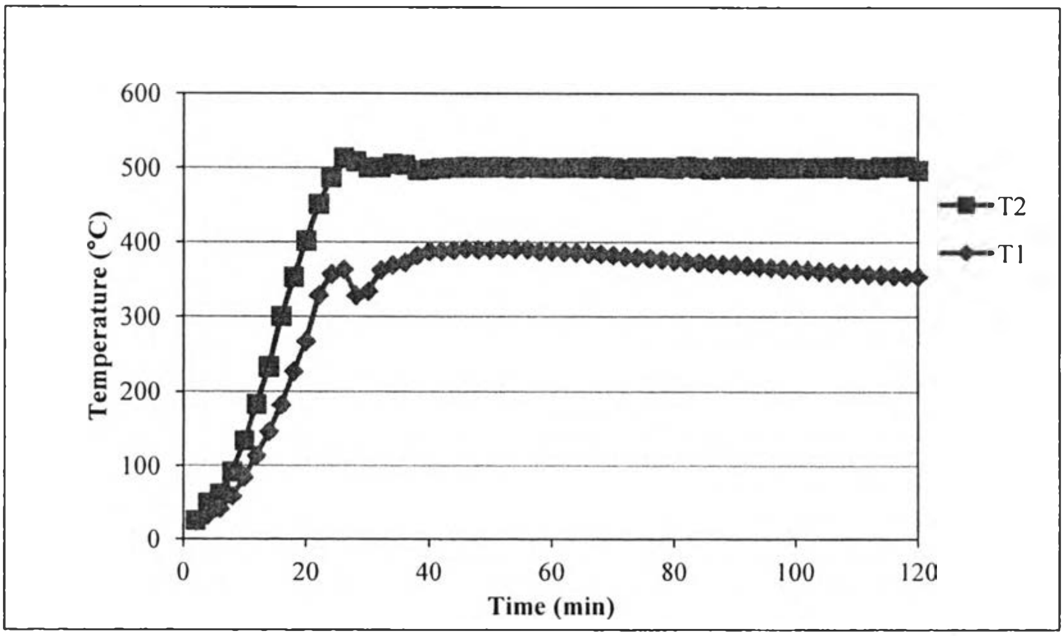



**Figure A12** Temperature profiles of waste tire pyrolysis with using 5%Fe/HBeta catalyst.

**Table A13** Pyrolysis conditions: 10%Fe/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 26.3 | 28.0 | 32 | 373.4 | 508.8 | 62 | 368.2 | 500.2 | 92 | 356.2 | 499.6 |
| 4 | 32.3 | 42.5 | 34 | 379.7 | 506.1 | 64 | 357.0 | 499.8 | 94 | 357.4 | 499.4 |
| 6 | 48.2 | 73.9 | 36 | 382.5 | 502.8 | 66 | 348.8 | 500.5 | 96 | 349.4 | 499.7 |
| 8 | 59.1 | 92.5 | 38 | 384.9 | 500.8 | 68 | 346.0 | 500.5 | 98 | 346.3 | 499.7 |
| 10 | 90.7 | 138.5 | 40 | 395.4 | 501.0 | 70 | 341.7 | 499.9 | 100 | 350.1 | 501.0 |
| 12 | 130.3 | 199.8 | 42 | 408.7 | 501.2 | 72 | 342.7 | 499.7 | 102 | 355.8 | 500.5 |
| 14 | 175.4 | 245.1 | 44 | 439.2 | 500.6 | 74 | 353.0 | 500.6 | 104 | 354.2 | 499.9 |
| 16 | 189.1 | 293.7 | 46 | 438.1 | 501.1 | 76 | 357.7 | 500.8 | 106 | 353.8 | 499.8 |
| 18 | 228.1 | 352.7 | 48 | 436.4 | 501.0 | 78 | 356.2 | 500.7 | 108 | 347.5 | 500.0 |
| 20 | 301.7 | 427.0 | 50 | 430.2 | 498.7 | 80 | 354.8 | 499.6 | 110 | 354.4 | 500.3 |
| 22 | 324.5 | 454.0 | 52 | 417.0 | 498.1 | 82 | 350.4 | 500.2 | 112 | 356.0 | 501.0 |
| 24 | 351.0 | 485.1 | 54 | 404.0 | 498.3 | 84 | 346.6 | 499.9 | 114 | 357.2 | 499.8 |
| 26 | 313.7 | 511.2 | 56 | 396.4 | 498.7 | 86 | 351.3 | 503.3 | 116 | 354.7 | 499.6 |
| 28 | 325.7 | 504.3 | 58 | 386.9 | 500.0 | 88 | 352.3 | 501.7 | 118 | 350.2 | 500.1 |
| 30 | 339.6 | 501.0 | 60 | 377.0 | 499.5 | 90 | 353.2 | 495.0 | 120 | 350.9 | 499.8 |

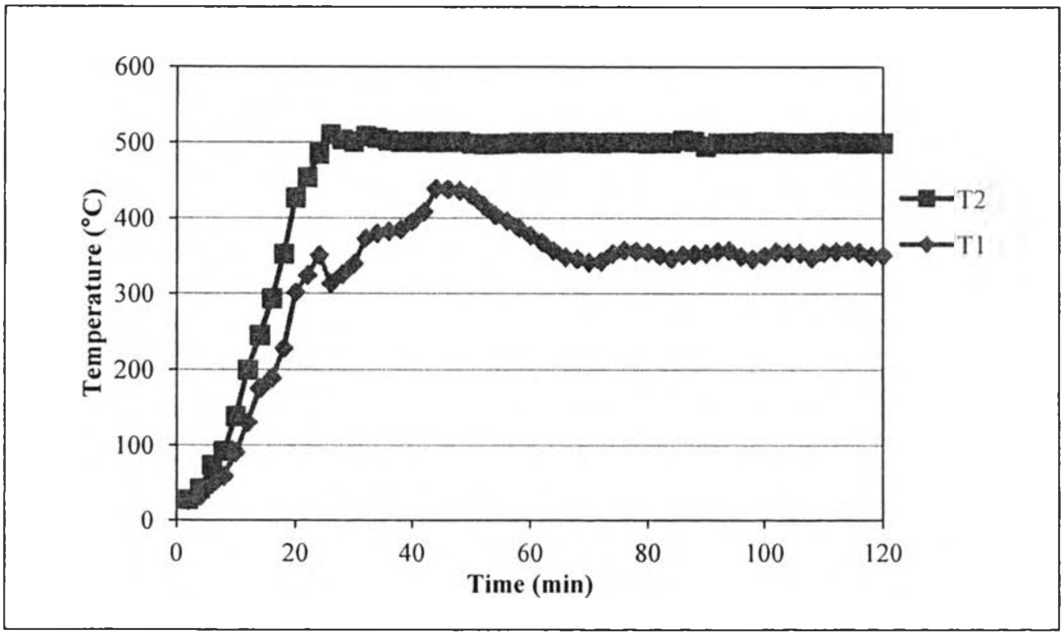



**Figure A13** Temperature profiles of waste tire pyrolysis with using 10%Fe/HBeta catalyst.

**Table A14** Pyrolysis conditions: 20%Fe/HBeta catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 25.4 | 27.4 | 32 | 345.9 | 526.0 | 62 | 358.8 | 497.2 | 92 | 352.4 | 500.1 |
| 4 | 30.4 | 38.6 | 34 | 421.1 | 524.4 | 64 | 356.4 | 500.2 | 94 | 354.2 | 500.1 |
| 6 | 48.7 | 70.6 | 36 | 425.4 | 513.7 | 66 | 352.8 | 500.4 | 96 | 354.7 | 499.5 |
| 8 | 69.6 | 104.2 | 38 | 420.5 | 498.7 | 68 | 353.2 | 500.7 | 98 | 356.0 | 499.9 |
| 10 | 98.7 | 136.7 | 40 | 412.9 | 503.2 | 70 | 354.0 | 497.8 | 100 | 357.1 | 496.9 |
| 12 | 113.7 | 175.9 | 42 | 399.7 | 500.7 | 72 | 355.0 | 499.1 | 102 | 353.6 | 501.6 |
| 14 | 163.6 | 237.8 | 44 | 398.6 | 497.2 | 74 | 354.6 | 499.7 | 104 | 350.4 | 500.0 |
| 16 | 193.7 | 287.6 | 46 | 386.9 | 493.1 | 76 | 350.6 | 499.5 | 106 | 352.7 | 499.6 |
| 18 | 230.2 | 333.8 | 48 | 377.4 | 499.8 | 78 | 345.6 | 502.9 | 108 | 346.2 | 504.1 |
| 20 | 277.7 | 388.3 | 50 | 369.4 | 499.3 | 80 | 347.2 | 505.2 | 110 | 350.9 | 501.5 |
| 22 | 344.2 | 445.3 | 52 | 363.1 | 501.8 | 82 | 351.1 | 502.0 | 112 | 354.0 | 499.0 |
| 24 | 346.3 | 467.8 | 54 | 354.0 | 500.0 | 84 | 352.7 | 495.3 | 114 | 356.5 | 499.7 |
| 26 | 306.7 | 473.5 | 56 | 347.3 | 499.1 | 86 | 349.1 | 499.2 | 116 | 354.9 | 499.8 |
| 28 | 328.6 | 531.1 | 58 | 350.1 | 502.9 | 88 | 347.7 | 505.1 | 118 | 351.7 | 499.2 |
| 30 | 356.9 | 529.1 | 60 | 352.8 | 503.1 | 90 | 351.5 | 500.7 | 120 | 349.9 | 499.8 |

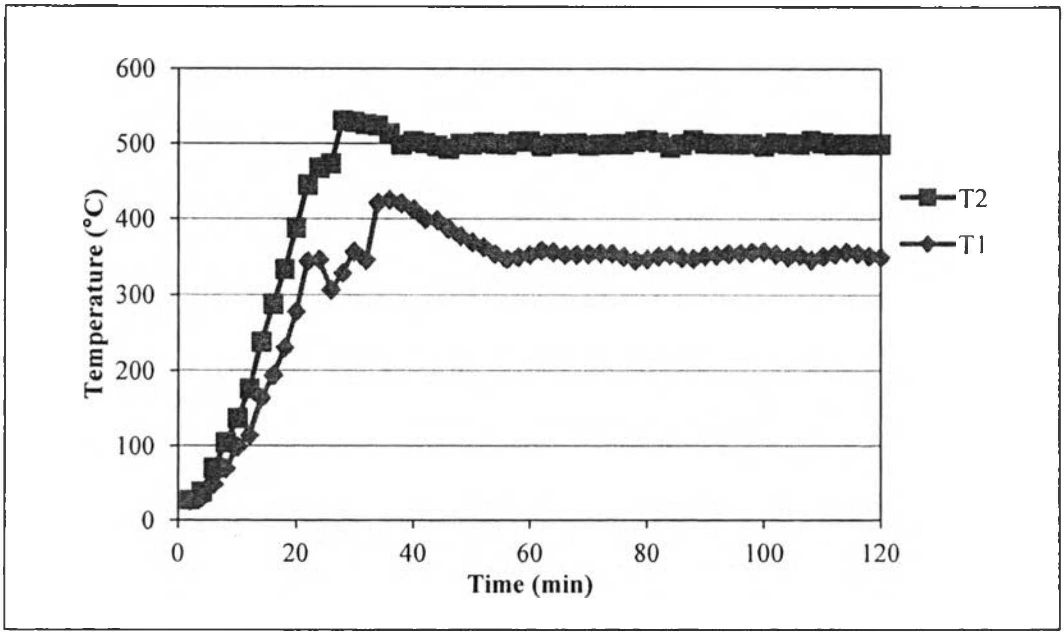



**Figure A14** Temperature profiles of waste tire pyrolysis with using 20%Fe/HBeta catalyst.

**Table A15** Pyrolysis conditions: 1%Ru/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 27.9 | 29.2 | 32 | 363.1 | 504.0 | 62 | 350.1 | 500.4 | 92 | 363.5 | 498.0 |
| 4 | 35.4 | 48.1 | 34 | 368.2 | 499.0 | 64 | 355.2 | 500.1 | 94 | 360.4 | 499.7 |
| 6 | 48.0 | 71.6 | 36 | 384.2 | 498.3 | 66 | 357.3 | 496.7 | 96 | 364.5 | 497.5 |
| 8 | 69.3 | 108.0 | 38 | 396.7 | 496.5 | 68 | 357.6 | 497.3 | 98 | 355.7 | 499.9 |
| 10 | 96.6 | 152.8 | 40 | 395.0 | 493.8 | 70 | 354.7 | 499.1 | 100 | 357.6 | 500.2 |
| 12 | 135.2 | 221.8 | 42 | 393.0 | 495.0 | 72 | 347.0 | 497.1 | 102 | 354.2 | 499.4 |
| 14 | 159.0 | 261.1 | 44 | 385.6 | 501.0 | 74 | 350.7 | 498.7 | 104 | 353.6 | 501.7 |
| 16 | 205.6 | 335.4 | 46 | 371.4 | 499.8 | 76 | 349.4 | 499.3 | 106 | 350.9 | 499.1 |
| 18 | 235.7 | 370.0 | 48 | 360.8 | 498.3 | 78 | 348.7 | 502.5 | 108 | 350.2 | 504.9 |
| 20 | 260.0 | 431.3 | 50 | 346.4 | 502.2 | 80 | 343.0 | 500.8 | 110 | 350.9 | 499.6 |
| 22 | 308.7 | 466.5 | 52 | 341.1 | 504.2 | 82 | 342.6 | 501.8 | 112 | 344.5 | 501.0 |
| 24 | 337.1 | 481.0 | 54 | 340.6 | 502.7 | 84 | 347.6 | 499.5 | 114 | 345.8 | 498.9 |
| 26 | 325.5 | 498.5 | 56 | 341.9 | 500.9 | 86 | 354.9 | 501.5 | 116 | 350.8 | 500.4 |
| 28 | 348.6 | 518.4 | 58 | 345.7 | 499.1 | 88 | 357.0 | 502.3 | 118 | 353.6 | 498.9 |
| 30 | 351.9 | 512.4 | 60 | 349.1 | 501.6 | 90 | 359.6 | 502.4 | 120 | 356.6 | 502.0 |

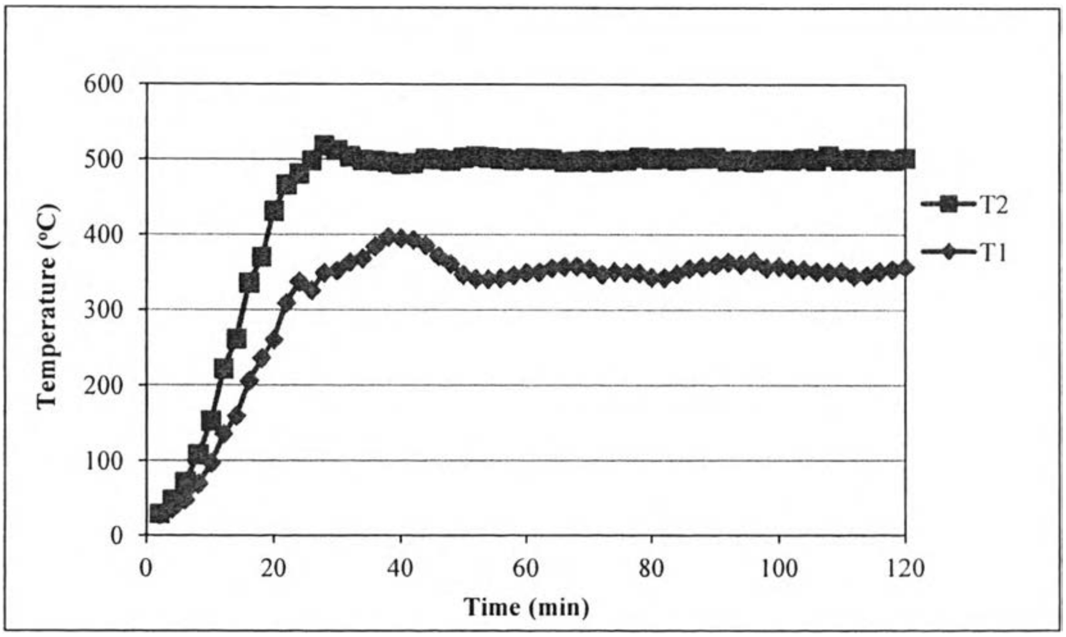



**Figure A15** Temperature profiles of waste tire pyrolysis with using 1%Ru/HMOR catalyst.

**Table A16** Pyrolysis conditions: 5%Fe/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 25.3 | 24.6 | 32 | 410.0 | 494.0 | 62 | 357.2 | 499.5 | 92 | 368.4 | 500.4 |
| 4 | 34.5 | 43.8 | 34 | 400.0 | 498.7 | 64 | 351.3 | 501.2 | 94 | 368.6 | 501.0 |
| 6 | 49.3 | 66.4 | 36 | 384.9 | 494.5 | 66 | 350.9 | 505.4 | 96 | 368.9 | 498.6 |
| 8 | 86.6 | 109.7 | 38 | 366.4 | 501.1 | 68 | 356.4 | 501.4 | 98 | 368.6 | 497.9 |
| 10 | 105.5 | 142.6 | 40 | 350.1 | 497.3 | 70 | 360.3 | 497.5 | 100 | 368.1 | 499.6 |
| 12 | 128.1 | 169.7 | 42 | 335.1 | 503.1 | 72 | 361.8 | 499.5 | 102 | 368.3 | 499.8 |
| 14 | 169.4 | 234.5 | 44 | 335.5 | 503.0 | 74 | 350.4 | 502.7 | 104 | 368.3 | 500.3 |
| 16 | 197.6 | 306.4 | 46 | 344.5 | 498.0 | 76 | 356.6 | 503.2 | 106 | 367.2 | 499.5 |
| 18 | 231.7 | 336.5 | 48 | 355.4 | 500.8 | 78 | 350.8 | 500.3 | 108 | 365.8 | 499.3 |
| 20 | 274.8 | 400.7 | 50 | 364.4 | 501.2 | 80 | 356.1 | 501.9 | 110 | 365.3 | 501.8 |
| 22 | 318.8 | 446.5 | 52 | 366.0 | 499.1 | 82 | 361.6 | 500.0 | 112 | 365.1 | 501.4 |
| 24 | 331.8 | 455.1 | 54 | 368.7 | 498.1 | 84 | 363.7 | 503.2 | 114 | 364.4 | 489.9 |
| 26 | 347.2 | 503.1 | 56 | 367.1 | 497.6 | 86 | 366.6 | 500.0 | 116 | 363.0 | 499.7 |
| 28 | 358.4 | 544.0 | 58 | 353.4 | 498.9 | 88 | 367.8 | 501.1 | 118 | 362.9 | 498.9 |
| 30 | 402.1 | 518.5 | 60 | 356.8 | 498.9 | 90 | 368.4 | 501.1 | 120 | 357.6 | 502.5 |

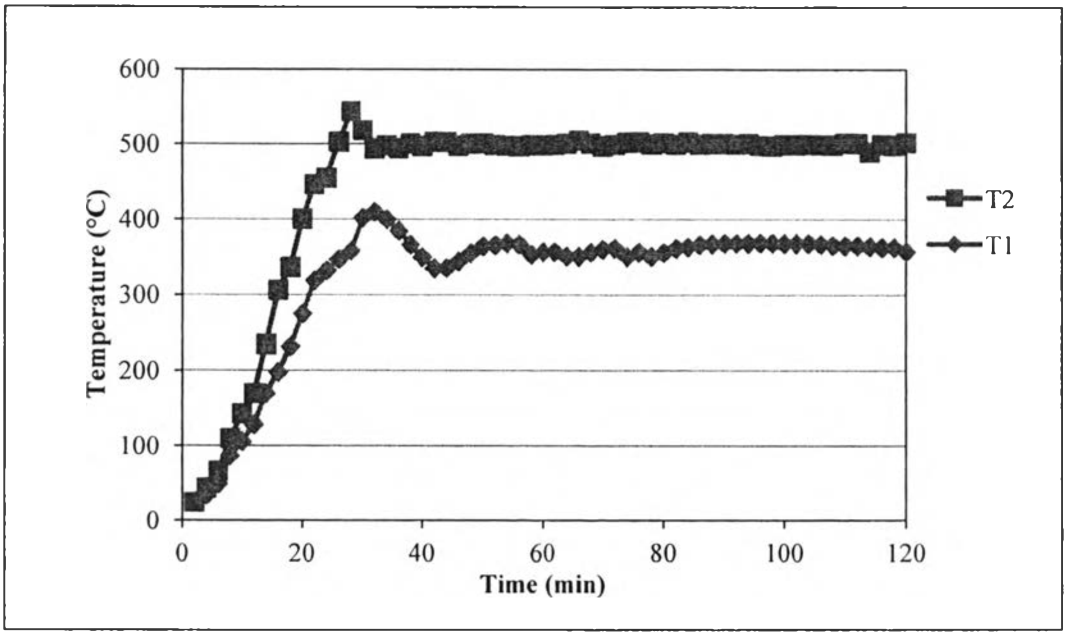



**Figure A16** Temperature profiles of waste tire pyrolysis with using 5%Fe/HMOR catalyst.

**Table A17** Pyrolysis conditions: 10%Fe/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 27.0 | 25.9 | 32 | 388.0 | 536.0 | 62 | 360.2 | 501.4 | 92 | 353.5 | 500.6 |
| 4 | 33.0 | 38.9 | 34 | 392.4 | 525.1 | 64 | 360.6 | 500.7 | 94 | 358.3 | 501.5 |
| 6 | 47.2 | 63.3 | 36 | 395.3 | 490.0 | 66 | 357.7 | 498.7 | 96 | 358.8 | 497.3 |
| 8 | 67.1 | 91.2 | 38 | 385.5 | 491.3 | 68 | 352.4 | 500.0 | 98 | 352.0 | 499.6 |
| 10 | 103.2 | 133.4 | 40 | 375.3 | 503.0 | 70 | 346.0 | 499.7 | 100 | 351.0 | 500.3 |
| 12 | 141.1 | 184.3 | 42 | 370.1 | 500.3 | 72 | 346.3 | 503.5 | 102 | 346.5 | 499.9 |
| 14 | 165.6 | 230.2 | 44 | 364.6 | 500.2 | 74 | 349.3 | 502.2 | 104 | 342.8 | 502.8 |
| 16 | 194.7 | 281.2 | 46 | 360.5 | 501.1 | 76 | 353.9 | 499.5 | 106 | 344.5 | 500.8 |
| 18 | 232.9 | 341.1 | 48 | 356.5 | 500.0 | 78 | 356.1 | 499.0 | 108 | 352.5 | 499.2 |
| 20 | 276.6 | 409.1 | 50 | 350.7 | 499.8 | 80 | 354.3 | 499.1 | 110 | 360.8 | 498.2 |
| 22 | 309.7 | 435.6 | 52 | 345.3 | 500.5 | 82 | 348.9 | 501.5 | 112 | 361.5 | 499.6 |
| 24 | 309.2 | 400.6 | 54 | 346.0 | 502.3 | 84 | 344.7 | 500.5 | 114 | 363.6 | 498.3 |
| 26 | 312.6 | 434.6 | 56 | 352.7 | 501.0 | 86 | 341.7 | 500.4 | 116 | 365.6 | 500.8 |
| 28 | 315.2 | 524.5 | 58 | 353.2 | 499.2 | 88 | 342.8 | 503.6 | 118 | 366.9 | 499.9 |
| 30 | 365.0 | 543.1 | 60 | 365.5 | 500.8 | 90 | 349.5 | 498.8 | 120 | 368.1 | 497.2 |

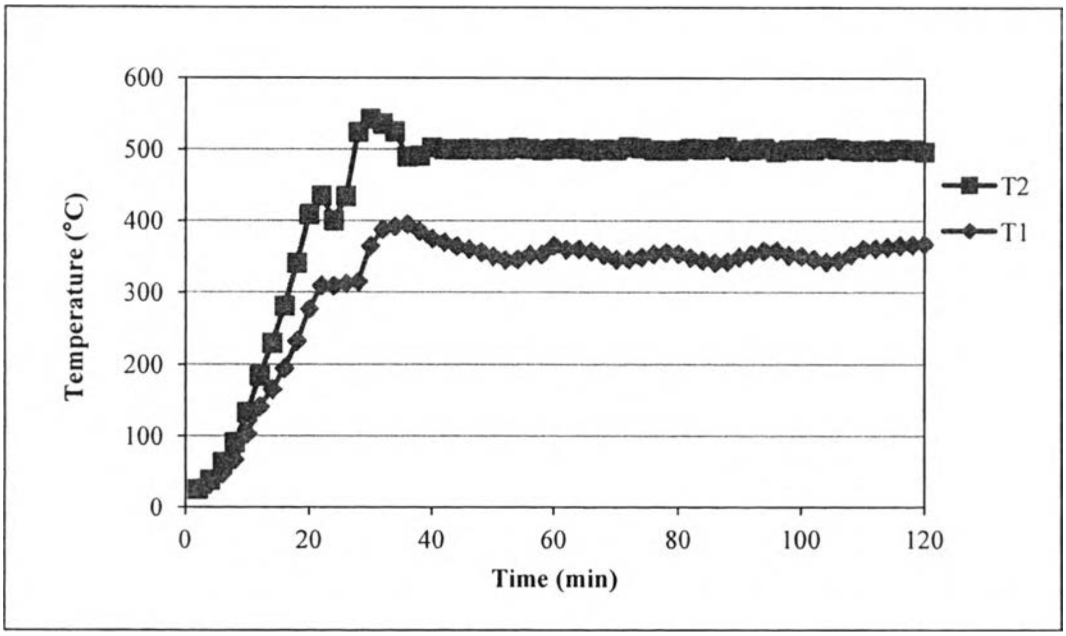



**Figure A17** Temperature profiles of waste tire pyrolysis with using 5%Fe/HBeta catalyst.

**Table A18** Pyrolysis conditions: 20%Fe/HMOR catalyst

Tire = 30 g, $N_2$ flow = 30 ml/min

Pyrolysis Temperature (T2) = 500 °C

Catalytic Temperature (T1) = 350 °C

| Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 | Time (min) | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 26.5 | 28.0 | 32 | 371.2 | 514.4 | 62 | 350.8 | 498.0 | 92 | 349.6 | 504.6 |
| 4 | 33.0 | 43.1 | 34 | 382.8 | 496.6 | 64 | 348.7 | 502.2 | 94 | 350.9 | 498.6 |
| 6 | 46.9 | 67.9 | 36 | 381.9 | 497.2 | 66 | 348.4 | 502.7 | 96 | 351.3 | 502.2 |
| 8 | 70.1 | 102.6 | 38 | 362.0 | 499.9 | 68 | 347.7 | 501.3 | 98 | 352.0 | 498.8 |
| 10 | 101.3 | 147.0 | 40 | 361.2 | 499.8 | 70 | 352.8 | 500.8 | 100 | 352.7 | 502.0 |
| 12 | 136.3 | 202.0 | 42 | 355.6 | 498.7 | 72 | 356.5 | 502.5 | 102 | 353.6 | 501.3 |
| 14 | 162.5 | 246.6 | 44 | 351.6 | 499.5 | 74 | 357.3 | 499.7 | 104 | 352.6 | 499.1 |
| 16 | 211.9 | 319.7 | 46 | 350.5 | 500.9 | 76 | 357.7 | 500.6 | 106 | 351.7 | 498.2 |
| 18 | 239.7 | 354.8 | 48 | 350.0 | 501.1 | 78 | 356.6 | 498.0 | 108 | 354.1 | 489.2 |
| 20 | 279.6 | 419.9 | 50 | 347.3 | 499.4 | 80 | 358.2 | 500.4 | 110 | 355.3 | 498.0 |
| 22 | 294.1 | 446.9 | 52 | 349.1 | 504.8 | 82 | 359.4 | 500.3 | 112 | 354.5 | 498.4 |
| 24 | 333.7 | 434.9 | 54 | 349.1 | 502.3 | 84 | 358.3 | 496.1 | 114 | 350.1 | 497.9 |
| 26 | 303.5 | 449.3 | 56 | 351.8 | 499.9 | 86 | 357.0 | 495.4 | 116 | 354.6 | 498.6 |
| 28 | 309.3 | 537.6 | 58 | 356.6 | 496.8 | 88 | 352.4 | 499.7 | 118 | 354.9 | 501.9 |
| 30 | 336.0 | 530.0 | 60 | 355.2 | 497.3 | 90 | 349.2 | 497.3 | 120 | 355.3 | 499.3 |

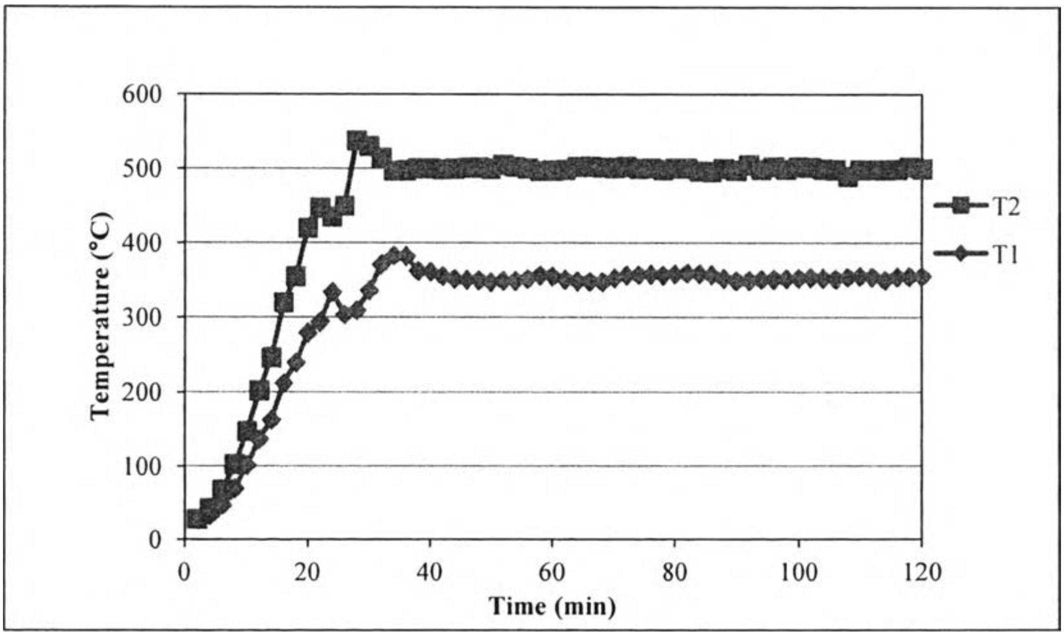



**Figure A18** Temperature profiles of waste tire pyrolysis with using 20%Fe/HBeta catalyst.

## Appendix B Yields of Pyrolysis Products

**Table B1** Yield of product distribution obtained from pyrolysis with 1%Pd/HBeta and varied Ni/HBeta

| Product | Non-cat | HBeta | 1%Pd/ HBeta | 5%Ni/ HBeta | 10%Ni/ HBeta | 20%Ni/ HBeta |
|---|---|---|---|---|---|---|
| Gas | 16.1 | 18.2 | 21.5 | 16.6 | 22.7 | 21.2 |
| Liquid | 40.0 | 33.0 | 35.7 | 42.1 | 33.2 | 34.2 |
| Solid | 44.1 | 48.9 | 42.8 | 41.3 | 44.4 | 44.6 |
| G/L ratio | 0.40 | 0.55 | 0.60 | 0.39 | 0.68 | 0.62 |

**Table B2** Yield of product distribution obtained from pyrolysis with 1%Pd/HMOR and varied Ni/HMOR

| Product | Non-cat | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| Gas | 16.1 | 18.8 | 18.6 | 24.2 | 17.7 | 18.3 |
| Liquid | 40.0 | 37.4 | 38.7 | 31.9 | 43.2 | 39.1 |
| Solid | 44.1 | 43.8 | 42.6 | 43.9 | 42.5 | 42.6 |
| G/L ratio | 0.40 | 0.50 | 0.48 | 0.76 | 0.41 | 0.47 |

**Table B3** Yield of product distribution obtained from pyrolysis with 1%Ru/HBeta and varied Fe/HBeta

| Product | Non-cat | Hbeta | 1%Ru/ HBeta | 5%Fe/ HBeta | 10%Fe/ HBeta | 20%Fe/ HBeta |
|---|---|---|---|---|---|---|
| Gas | 16.1 | 18.2 | 24.3 | 20.5 | 27.8 | 15.2 |
| Liquid | 40.0 | 33.0 | 33.4 | 36.8 | 30.3 | 42.5 |
| Solid | 44.1 | 48.9 | 42.4 | 42.7 | 41.9 | 42.3 |
| G/L ratio | 0.40 | 0.55 | 0.73 | 0.56 | 0.92 | 0.36 |

**Table B4** Yield of product distribution obtained from pyrolysis with 1%Ru/HMOR and varied Fe/HMOR

| Product | Non-cat | HMOR | 1%Ru/ HMOR | 5%Fe/ HMOR | 10%Fe/ HMOR | 20%Fe/ HMOR |
|---|---|---|---|---|---|---|
| Gas | 16.1 | 18.8 | 21.1 | 14.8 | 17.1 | 22.2 |
| Liquid | 40.0 | 37.4 | 35.9 | 42.1 | 39.0 | 34.6 |
| Solid | 44.1 | 43.8 | 42.9 | 43.1 | 43.9 | 43.3 |
| G/L ratio | 0.40 | 0.50 | 0.59 | 0.35 | 0.44 | 0.64 |

**Table B5** Yield of gas composition obtained from pyrolysis with 1%Pd/HBeta and varied Ni/HBeta

| Products distribution (%yield) | Non-Catalyst | HBeta | 1%Pd/ HBeta | 5%Ni/ HBeta | 10%Ni/ HBeta | 20%Ni/ HBeta |
|---|---|---|---|---|---|---|
| **Methane** | 3.52 | 1.72 | 3.00 | 2.12 | 4.00 | 3.84 |
| **Ethylene** | 1.65 | 0.70 | 1.35 | 1.16 | 1.89 | 1.55 |
| **Ethane** | 2.87 | 1.55 | 3.02 | 2.12 | 3.52 | 3.41 |
| **Propylene** | 1.83 | 1.18 | 2.20 | 1.80 | 2.53 | 2.28 |
| **Propane** | 1.45 | 1.66 | 2.23 | 1.54 | 2.02 | 2.14 |
| **C4** | 3.23 | 5.51 | 6.49 | 4.82 | 5.25 | 5.10 |
| **C5** | 1.30 | 4.55 | 2.55 | 2.24 | 2.53 | 2.22 |
| **C6+** | 0.22 | 1.33 | 0.62 | 0.80 | 0.97 | 0.65 |
| **Total** | 16.1 | 18.2 | 21.5 | 16.6 | 22.7 | 21.2 |

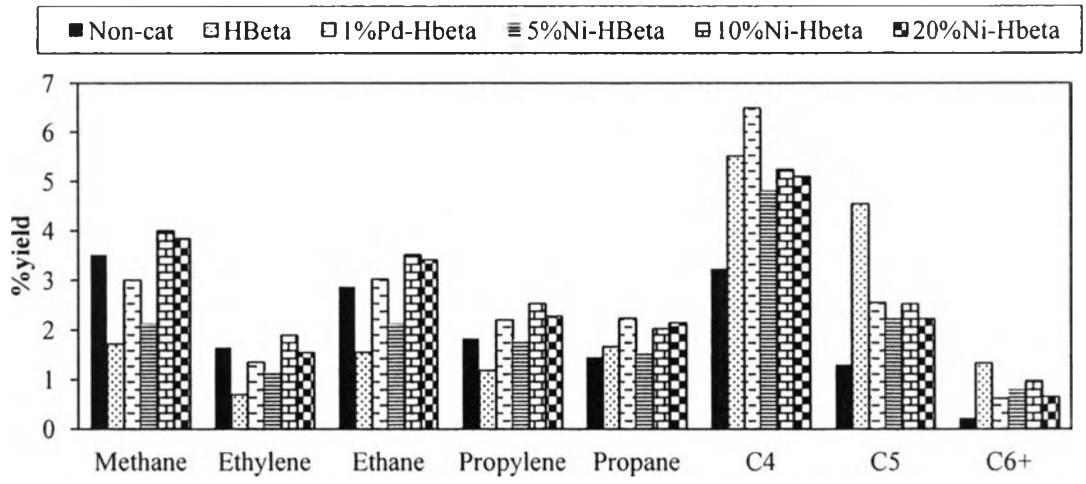


**Table B6** Yield of gas composition obtained from pyrolysis with 1%Pd/HMOR and varied Ni/HMOR

| Products distribution (%yield) | Non-Catalyst | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| **Methane** | 3.52 | 4.11 | 3.92 | 5.41 | 3.73 | 3.81 |
| **Ethylene** | 1.65 | 1.20 | 1.10 | 1.49 | 1.10 | 1.11 |
| **Ethane** | 2.87 | 3.59 | 3.60 | 4.77 | 3.35 | 3.54 |
| **Propylene** | 1.83 | 1.18 | 1.47 | 2.07 | 1.69 | 0.99 |
| **Propane** | 1.45 | 3.50 | 2.77 | 3.30 | 2.12 | 3.08 |
| **C4** | 3.23 | 3.61 | 3.85 | 4.54 | 3.66 | 3.80 |
| **C5** | 1.30 | 1.27 | 1.52 | 2.00 | 1.57 | 1.51 |
| **C6+** | 0.22 | 0.31 | 0.40 | 0.64 | 0.46 | 0.47 |
| **Total** | 16.1 | 18.8 | 18.6 | 24.2 | 17.7 | 18.3 |

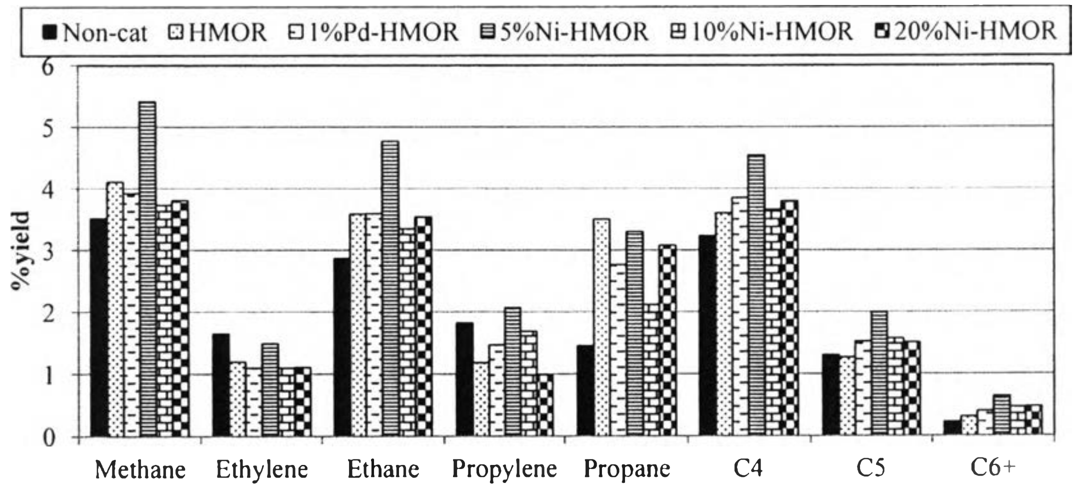


**Table B7** Yield of gas composition obtained from pyrolysis with 1%Ru/HBeta and varied Fe/HBeta

| Products distribution (%yield) | Non-Catalyst | HBeta | 1%Ru/ HBeta | 5%Fe/ HBeta | 10%Fe/ HBeta | 20%Fe/ HBeta |
|---|---|---|---|---|---|---|
| **Methane** | 3.52 | 1.72 | 3.66 | 3.87 | 4.55 | 2.49 |
| **Ethylene** | 1.65 | 0.70 | 1.44 | 1.45 | 1.66 | 1.30 |
| **Ethane** | 2.87 | 1.55 | 3.79 | 3.44 | 4.14 | 2.68 |
| **Propylene** | 1.83 | 1.18 | 2.02 | 2.30 | 3.33 | 1.73 |
| **Propane** | 1.45 | 1.66 | 2.99 | 1.85 | 3.29 | 1.60 |
| **C4** | 3.23 | 5.51 | 7.21 | 5.23 | 8.63 | 3.69 |
| **C5** | 1.30 | 4.55 | 2.97 | 1.83 | 2.39 | 1.52 |
| **C6+** | 0.22 | 1.33 | 0.62 | 0.54 | 0.55 | 0.39 |
| **Total** | 16.1 | 18.2 | 24.7 | 20.5 | 28.5 | 15.4 |

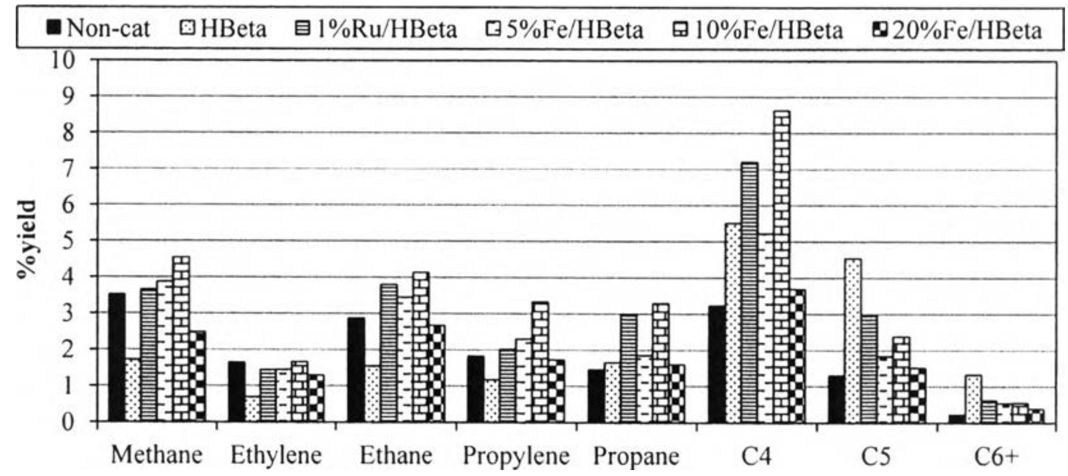
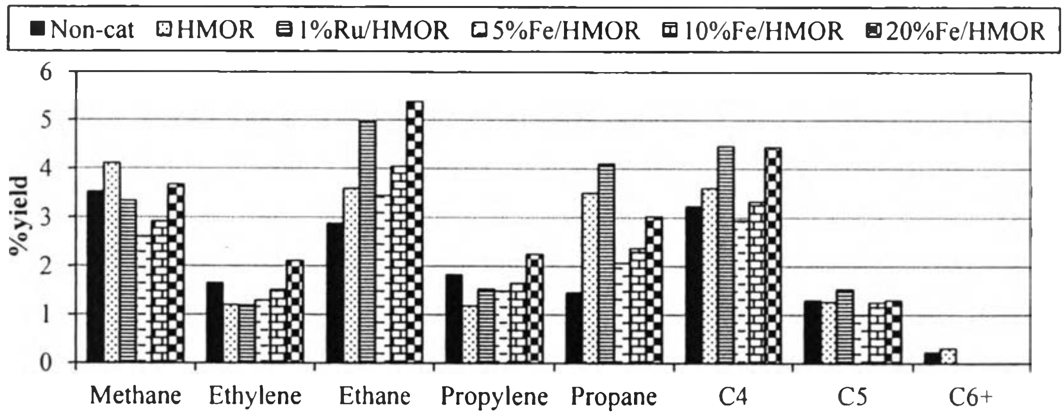


**Table B8** Yield of gas composition obtained from pyrolysis with 1%Ru/HMOR and varied Fe/HMOR

| Products distribution (%yield) | Non-Catalyst | HMOR | 1%Ru/ HMOR | 5%Fe/ HMOR | 10%Fe/ HMOR | 20%Fe/ HMOR |
|---|---|---|---|---|---|---|
| **Methane** | 3.52 | 4.11 | 3.34 | 2.60 | 2.91 | 3.67 |
| **Ethylene** | 1.65 | 1.20 | 1.19 | 1.30 | 1.51 | 2.10 |
| **Ethane** | 2.87 | 3.59 | 4.97 | 3.44 | 4.04 | 5.38 |
| **Propylene** | 1.83 | 1.18 | 1.53 | 1.49 | 1.65 | 2.25 |
| **Propane** | 1.45 | 3.50 | 4.11 | 2.07 | 2.37 | 3.02 |
| **C4** | 3.23 | 3.61 | 4.47 | 2.94 | 3.33 | 4.45 |
| **C5** | 1.30 | 1.27 | 1.53 | 1.00 | 1.25 | 1.30 |
| **C6+** | 0.22 | 0.31 | 0 | 0 | 0 | 0 |
| **Total** | 16.1 | 18.8 | 21.1 | 14.8 | 17.1 | 22.2 |



**Appendix C Liquid Composition in Maltenes**

**Table C1** Concentration of liquid compositions obtained from pyrolysis with 1%Pd/HBeta and varied Ni/HBeta

| Liquid compositions (%wt) | Non-Catalyst | HBeta | 1%Pd/ HBeta | 5%Ni/ HBeta | 10%Ni/ HBeta | 20%Ni/ HBeta |
|---|---|---|---|---|---|---|
| Saturated hydrocarbons | 56.5 | 66.2 | 56.3 | 60.6 | 59.2 | 53.3 |
| Mono-aromatics | 6.61 | 10.5 | 27.8 | 14.3 | 11.7 | 10.3 |
| Di- aromatics | 9.23 | 8.60 | 2.38 | 5.82 | 2.72 | 2.11 |
| Poly- aromatics | 7.45 | 5.22 | 4.75 | 6.61 | 13.0 | 10.0 |
| Polar- aromatics | 20.2 | 9.53 | 8.79 | 12.7 | 13.3 | 24.3 |

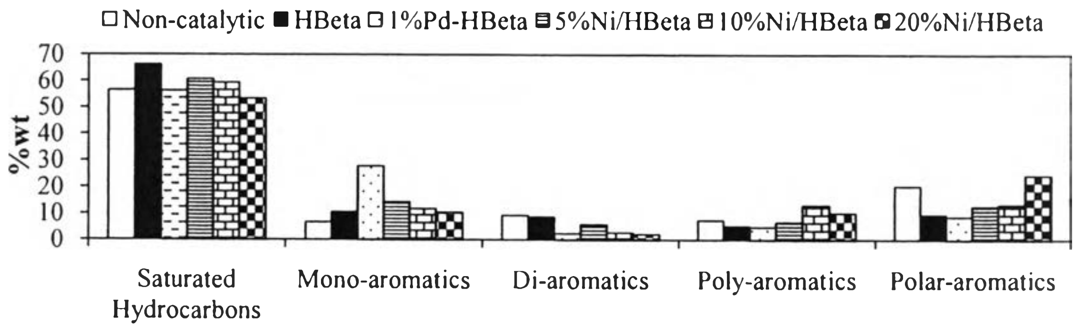



**Table C2** Concentration of liquid compositions obtained from pyrolysis with 1%Pd/HMOR and varied Ni/HMOR

| Liquid compositions (%wt) | Non-Catalyst | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| Saturated hydrocarbons | 56.5 | 59.1 | 64.0 | 51.7 | 57.0 | 61.5 |
| Mono-aromatics | 6.61 | 16.0 | 10.3 | 6.62 | 8.18 | 6.01 |
| Di- aromatics | 9.23 | 4.62 | 3.35 | 4.33 | 2.95 | 2.00 |
| Poly- aromatics | 7.45 | 11.1 | 4.19 | 16.3 | 18.9 | 4.29 |
| Polar- aromatics | 20.2 | 9.23 | 18.2 | 21.1 | 13.0 | 26.2 |

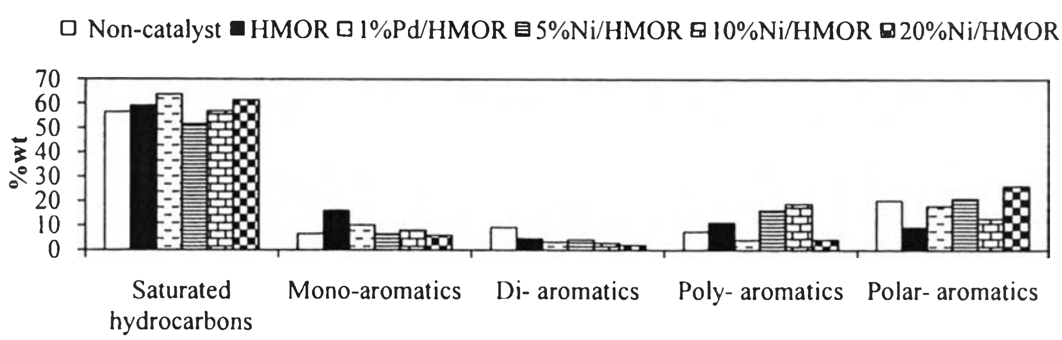


**Table C3** Concentration of liquid compositions obtained from pyrolysis with 1%Ru/HBeta and varied Fe/HBeta

| Liquid compositions (%wt) | Non-Catalyst | HBeta | 1%Ru/ HBeta | 5%Fe/ HBeta | 10%Fe/ HBeta | 20%Fe/ HBeta |
|---|---|---|---|---|---|---|
| Saturated hydrocarbons | 56.5 | 66.2 | 62.5 | 61.2 | 72.9 | 76.1 |
| Mono-aromatics | 6.61 | 10.5 | 10.3 | 5.74 | 10.7 | 8.76 |
| Di- aromatics | 9.23 | 8.60 | 2.95 | 2.73 | 3.46 | 1.81 |
| Poly- aromatics | 7.45 | 5.22 | 8.26 | 3.83 | 3.75 | 3.63 |
| Polar- aromatics | 20.2 | 9.53 | 15.9 | 26.5 | 9.22 | 9.67 |

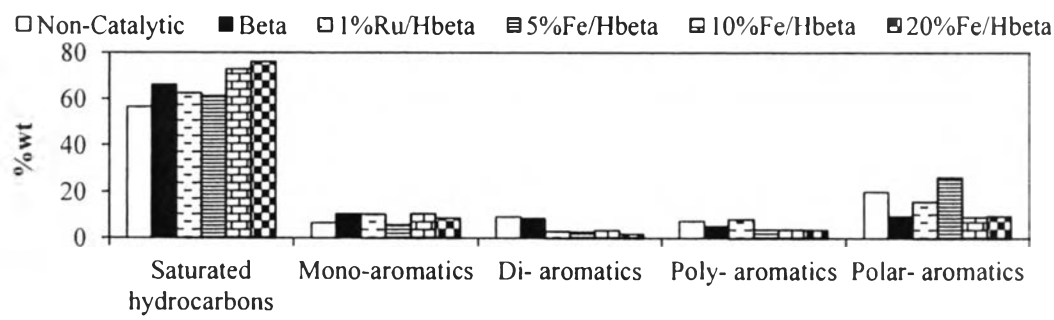
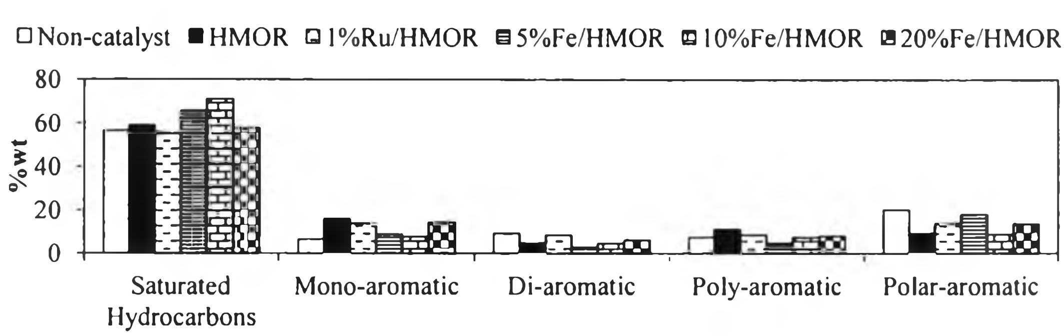



**Table C4** Concentration of liquid compositions obtained from pyrolysis with 1%Ru/HMOR and varied Fe/HMOR

| Liquid compositions (%wt) | Non-Catalyst | HMOR | 1%Ru/H MOR | 5%Fe/ HMOR | 10%Fe/H MOR | 20%Fe/H MOR |
|---|---|---|---|---|---|---|
| Saturated hydrocarbons | 56.5 | 59.1 | 55.2 | 65.9 | 71.3 | 57.8 |
| Mono-aromatics | 6.61 | 16.0 | 13.8 | 8.73 | 7.73 | 14.4 |
| Di- aromatics | 9.23 | 4.62 | 8.44 | 2.65 | 4.70 | 6.15 |
| Poly- aromatics | 7.45 | 11.1 | 8.70 | 4.76 | 7.46 | 8.02 |
| Polar- aromatics | 20.2 | 9.23 | 13.8 | 18.0 | 8.84 | 13.6 |



## Appendix D Petroleum Fractions of Derived Oils

**Table D1** Petroleum fractions in maltenes obtained from pyrolysis with 1%Pd/HBeta and varied Ni/HBeta

| Petroleum fraction | Non-catalyst | HBeta | 1%Pd/ HBeta | 5%Ni/ HBeta | 10%Ni/ HBeta | 20%Ni/ HBeta |
|---|---|---|---|---|---|---|
| Full range naphtha | 26.0 | 49.5 | 21.0 | 21.5 | 13.5 | 22.0 |
| Kerosene | 15.0 | 17.4 | 22.5 | 18.5 | 14.5 | 16.5 |
| Light gas oil | 19.5 | 13.5 | 20.0 | 20.0 | 24.0 | 26.5 |
| Heavy gas oil | 21.0 | 8.18 | 15.5 | 19.0 | 21.0 | 23.0 |
| Long residue | 16.5 | 11.5 | 15.0 | 21.0 | 27.0 | 11.0 |

**Table D2** Petroleum fractions in maltenes obtained from pyrolysis with 1%Pd/HMOR and varied Ni/HMOR

| Petroleum fraction | Non-catalyst | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| Full range naphtha | 26.0 | 33.3 | 26.5 | 26.1 | 17.8 | 25.8 |
| Kerosene | 15.0 | 17.6 | 13.0 | 15.9 | 13.5 | 14.1 |
| Light gas oil | 19.5 | 20.5 | 17.7 | 19.5 | 21.2 | 19.2 |
| Heavy gas oil | 21.0 | 16.6 | 21.1 | 18.3 | 26.3 | 19.2 |
| Long residue | 16.5 | 12.0 | 20.8 | 20.1 | 20.3 | 21.3 |

**Table D3** Petroleum fractions in maltenes obtained from pyrolysis with 1%Ru/HBeta and varied Fe/HBeta

| Petroleum fraction | Non-catalyst | HBeta | 1%Ru/ HBeta | 5%Fe/ HBeta | 10%Fe/ HBeta | 20%Fe/ HBeta |
|---|---|---|---|---|---|---|
| **Full range naphtha** | 26.0 | 49.5 | 34.5 | 42.2 | 37.6 | 33.6 |
| **Kerosene** | 15.0 | 17.4 | 18.6 | 18.5 | 21.2 | 18.9 |
| **Light gas oil** | 19.5 | 13.5 | 13.3 | 19.7 | 17.5 | 17.6 |
| **Heavy gas oil** | 21.0 | 8.18 | 11.6 | 9.73 | 11.9 | 13.1 |
| **Long residue** | 16.5 | 11.5 | 19.2 | 8.02 | 11.7 | 15.9 |

**Table D4** Petroleum fractions in maltenes obtained from pyrolysis with 1%Ru/HMOR and varied Fe/HMOR

| Petroleum fraction | Non-catalyst | HMOR | 1%Ru/H MOR | 5%Fe/H MOR | 10%Fe/H MOR | 20%Fe/H MOR |
|---|---|---|---|---|---|---|
| Full range naphtha | 26.0 | 33.3 | 39.9 | 37.5 | 39.3 | 37.3 |
| Kerosene | 15.0 | 17.6 | 21.2 | 14.5 | 21.8 | 20.6 |
| Light gas oil | 19.5 | 20.5 | 14.8 | 14.8 | 16.6 | 17.3 |
| Heavy gas oil | 21.0 | 16.6 | 11.4 | 15.4 | 10.7 | 13.0 |
| Long residue | 16.5 | 12.0 | 11.6 | 13.4 | 11.4 | 11.9 |

## Appendix E Composition of Char, Coke, and Asphaltenes

**Table E1** Char, Coke, and Asphaltenes obtained from pyrolysis with 1%Pd/HBeta and varied Ni/HBeta

| Composition (%wt) | Non-catalyst | HBeta | 1%Pd/ HBeta | 5%Ni/ HBeta | 10%Ni/ HBeta | 20%Ni/ HBeta |
|---|---|---|---|---|---|---|
| **Char** | 44.1 | 48.9 | 42.8 | 41.3 | 44.4 | 44.6 |
| **Coke** | - | 22.4 | 31.4 | 25.1 | 24.5 | 21.9 |
| **Asphaltene** | 0.097 | 0.092 | 0.014 | 0.104 | 0.114 | 0.115 |

**Table E2** Char, Coke, and Asphaltenes obtained from pyrolysis with 1%Pd/HMOR and varied Ni/HMOR

| Composition (%wt) | Non-catalyst | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| **Char** | 44.1 | 43.8 | 42.6 | 43.9 | 42.5 | 42.6 |
| **Coke** | - | 15.3 | 17.6 | 23.7 | 16.0 | 13.4 |
| **Asphaltene** | 0.097 | 0.113 | 0.323 | 0.112 | 0.196 | 0.127 |

**Table E3** Char, Coke, and Asphaltenes obtained from pyrolysis with 1%Ru/HBeta and varied Fe/HBeta

| Composition (%wt) | Non-catalyst | Hbeta | 1%Ru/ HBeta | 5%Fe/ HBeta | 10%Fe/ HBeta | 20%Fe/ HBeta |
|---|---|---|---|---|---|---|
| **Char** | 44.1 | 48.9 | 42.4 | 42.7 | 41.9 | 42.3 |
| **Coke** | - | 22.4 | 29.2 | 21.0 | 18.4 | 11.6 |
| **Asphaltene** | 0.097 | 0.092 | 0.128 | 0.074 | 0.383 | 0.127 |

**Table E4** Char, Coke, and Asphaltenes obtained from pyrolysis with 1%Ru/HMOR and varied Fe/HMOR

| Composition (%wt) | Non-catalyst | HMOR | 1%Ru/ HMOR | 5%Fe/ HMOR | 10%Fe/ HMOR | 20%Fe/ HMOR |
|---|---|---|---|---|---|---|
| **Char** | 44.1 | 43.8 | 42.9 | 43.1 | 43.9 | 43.3 |
| **Coke** | - | 15.3 | 16.6 | 11.4 | 7.70 | 6.18 |
| **Asphaltene** | 0.097 | 0.113 | 0.136 | 0.257 | 0.259 | 0.117 |

## Appendix F Sulfur in Derived Oils and Sulfur Deposition on Spent Catalysts

**Table F1** Sulfur in derived oils and sulfur deposition on spent catalyst obtained from pyrolysis with 1%Pd/HBeta and varied Ni/HBeta

| Catalyst | Metal Loading(%) | Sulfur (%wt) | |
|---|---|---|---|
| | | Spent Catalyst | Derived Oil s |
| Non-catalyst | - | - | 0.822 |
| HBeta | 0 | 0.722 | 0.876 |
| Pd/HBeta | 1 | 0.669 | 0.949 |
| Ni/HBeta | 5 | 1.38 | 0.808 |
| | 10 | 1.31 | 0.599 |
| | 20 | 1.39 | 0.686 |

**Table F2** Sulfur in derived oils and sulfur deposition on spent catalyst obtained from pyrolysis with 1%Pd/HMOR and varied Ni/HMOR

| Catalyst | Metal Loading(%) | Sulfur (%wt) | |
|---|---|---|---|
| | | Spent Catalyst | Derived Oil s |
| HMOR | 0 | 0.376 | 0.941 |
| Pd/HMOR | 1 | 0.49 | 1.07 |
| Ni/HMOR | 5 | 1.35 | 0.892 |
| | 10 | 1.70 | 1.07 |
| | 20 | 1.38 | 1.04 |

**Table F3** Sulfur in derived oils and sulfur deposition on spent catalyst obtained from pyrolysis with 1%Ru/HBeta and varied Fe/HBeta

| Catalyst | Metal Loading(%) | Sulfur (%wt) | |
|---|---|---|---|
| | | Spent Catalyst | Derived Oil s |
| HBeta | 0 | 0.722 | 0.876 |
| Ru/HBeta | 1 | 0.79 | 0.959 |
| Fe/HBeta | 5 | 1.53 | 0.878 |
| | 10 | 1.76 | 0.914 |
| | 20 | 1.57 | 1.15 |

**Table F4** Sulfur in derived oils and sulfur deposition on spent catalyst obtained from pyrolysis with 1%Ru/HMOR and varied Fe/HMOR

| Catalyst | Metal Loading(%) | Sulfur (%wt) | |
|---|---|---|---|
| | | Spent Catalyst | Derived Oil s |
| HMOR | 0 | 0.376 | 0.941 |
| Ru/HMOR | 1 | 0.332 | 1.08 |
| Fe/HMOR | 5 | 1.26 | 1.17 |
| | 10 | 1.63 | 1.10 |
| | 20 | 1.67 | 1.03 |

## Appendix G True Boiling Point Curves of Compositions in Pyrolytic Oils

**Table G1** True boiling point curves: - non catalytic case

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 60.8 | 69.0 | 61.0 | 46.6 | 59.7 | 33.9 |
| 5 | 122.7 | 199.7 | 232.1 | 61.0 | 191.8 | 85.5 |
| 10 | 148.4 | 224.3 | 272.3 | 63.9 | 234.4 | 145.9 |
| 15 | 154.9 | 241.3 | 292.9 | 66.5 | 255.3 | 211 |
| 20 | 172.5 | 253.2 | 309.8 | 69.3 | 275.1 | 235.5 |
| 25 | 192.0 | 261.1 | 322.0 | 78.7 | 305.0 | 252.4 |
| 30 | 215.3 | 270.7 | 336.0 | 228.3 | 331.8 | 270.9 |
| 35 | 231.3 | 279.1 | 350.3 | 254.3 | 351.5 | 288.2 |
| 40 | 246.5 | 289.3 | 363.7 | 272.9 | 373.7 | 310.7 |
| 45 | 257.8 | 296.9 | 374.3 | 368.7 | 389.3 | 331.8 |
| 50 | 270.6 | 307.5 | 382.8 | 392.2 | 403.3 | 351.3 |
| 55 | 284.2 | 315.4 | 389.4 | 412.9 | 416.6 | 366.3 |
| 60 | 295.6 | 325.0 | 396.8 | 425.5 | 427.5 | 382.8 |
| 65 | 309.9 | 334.3 | 405.4 | 440.1 | 438.5 | 398.4 |
| 70 | 323.0 | 346.5 | 416.1 | 454.3 | 448.1 | 416.7 |
| 75 | 338.2 | 361.2 | 426.5 | 472.5 | 458.4 | 435.9 |
| 80 | 359.6 | 376.7 | 437.9 | 489.7 | 467.9 | 454.0 |
| 85 | 381.9 | 394.6 | 452.5 | 510.4 | 476.3 | 469.9 |
| 90 | 409.6 | 421.5 | 471.8 | 530.0 | 487.2 | 484.4 |
| 95 | 457.8 | 457.7 | 497.5 | 548.7 | 513.2 | 515.0 |
| 100 | 545.6 | 533.7 | 561.2 | 585.3 | 562.2 | 562.8 |

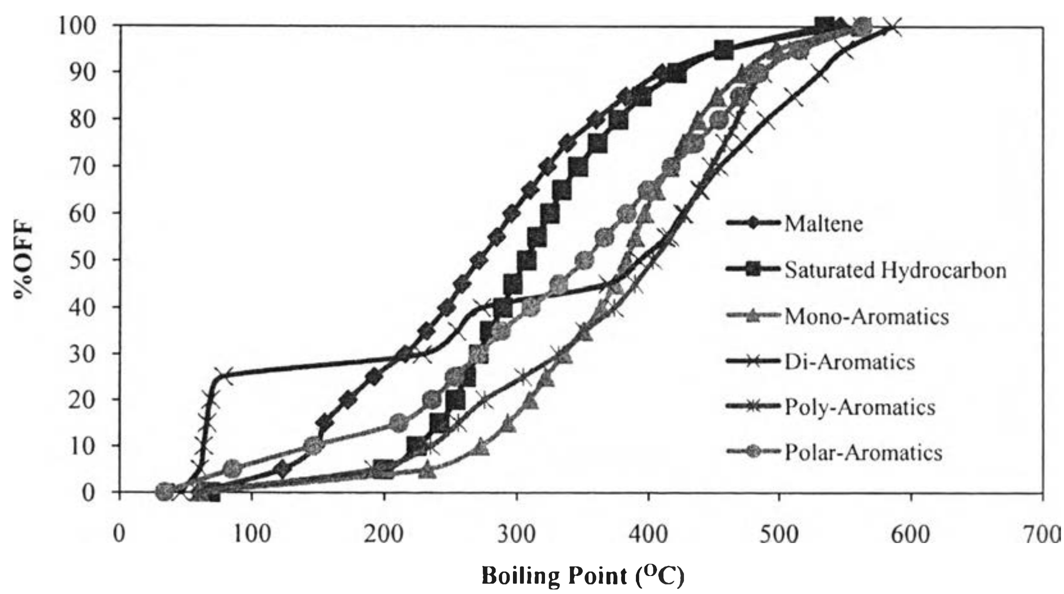



**Figure G1** True boiling point curves of Non-catalytic case.

**Table G2** True boiling point curves: - 1%Pd-HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 61.7 | 61.9 | 61.8 | 61.6 | 61.4 | 54.7 |
| **5** | 63.7 | 64.9 | 63.8 | 62.7 | 62.0 | 61.7 |
| **10** | 143.9 | 89.3 | 70.4 | 63.6 | 62.4 | 62.1 |
| **15** | 157.5 | 171.1 | 73.1 | 72.5 | 62.8 | 62.3 |
| **20** | 176.3 | 191.2 | 78.5 | 84.6 | 63.1 | 62.6 |
| **25** | 193.9 | 207.7 | 86.8 | 169.7 | 63.4 | 62.8 |
| **30** | 209.3 | 214.9 | 178.4 | 235.1 | 63.7 | 63.0 |
| **35** | 219.5 | 225.7 | 213.6 | 321.7 | 63.9 | 63.3 |
| **40** | 231.5 | 234.6 | 236.7 | 333.4 | 64.6 | 63.5 |
| **45** | 239.3 | 240.1 | 259.2 | 338.0 | 84.9 | 63.8 |
| **50** | 251.3 | 249.8 | 282.4 | 353.9 | 86.2 | 64.0 |
| **55** | 261.4 | 258.0 | 297.2 | 362.5 | 332.8 | 64.3 |
| **60** | 275.3 | 268.3 | 308.2 | 372.6 | 375.0 | 64.5 |
| **65** | 289.6 | 277.3 | 319.9 | 383.4 | 434.7 | 64.8 |
| **70** | 302.8 | 289.8 | 333.9 | 397.0 | 455.5 | 66.1 |
| **75** | 318.6 | 300.2 | 343.5 | 412.1 | 482.6 | 220.1 |
| **80** | 339.5 | 313.0 | 365.8 | 433.3 | 498.1 | 501.5 |
| **85** | 376.8 | 332.7 | 386.5 | 448.9 | 509.1 | 515.9 |
| **90** | 431.9 | 373.4 | 416.6 | 479.8 | 523.3 | 527.6 |
| **95** | 483.8 | 452.9 | 455.9 | 510.7 | 535.1 | 539.2 |
| **100** | 542.6 | 540.3 | 541.2 | 548.8 | 556.8 | 547.1 |

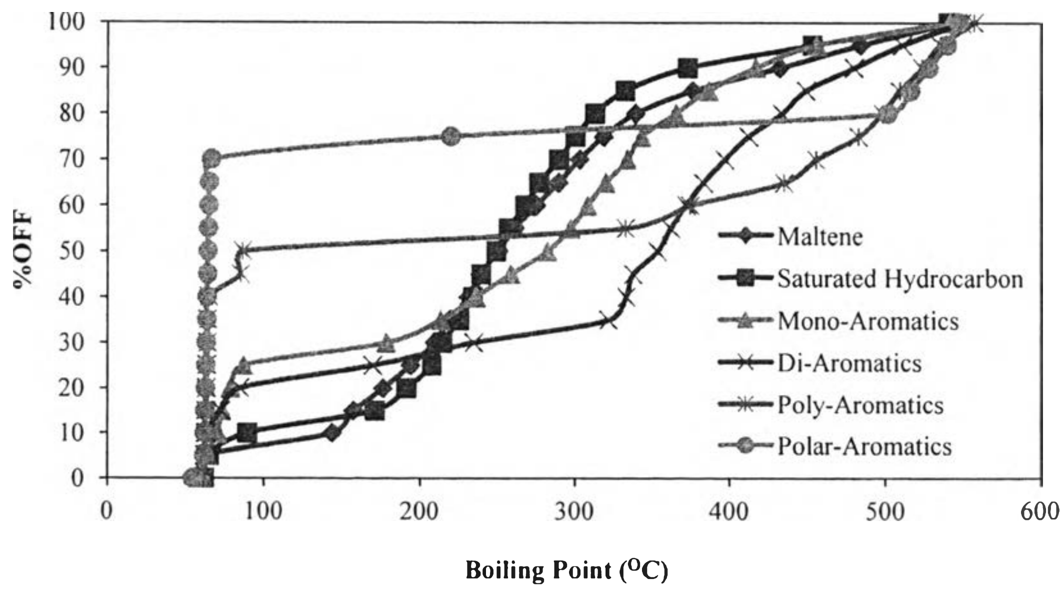



**Figure G2** True boiling point curves of 1%Pd-HBeta catalyst.

**Table G3** True boiling point curves: - 5%Ni-HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 64.4 | 64.4 | 64.3 | 64.3 | 64.2 | 63.5 |
| 5 | 147.4 | 169.3 | 104.7 | 101.6 | 104.4 | 64.6 |
| 10 | 153.4 | 193.7 | 298.6 | 331.9 | 105.1 | 95.8 |
| 15 | 173.4 | 213.2 | 304.5 | 343.1 | 108.8 | 226.0 |
| 20 | 193.4 | 223.3 | 315.1 | 356.1 | 109.0 | 250.3 |
| 25 | 212.9 | 236.4 | 321.8 | 373.2 | 109.3 | 281.6 |
| 30 | 224.5 | 243.9 | 327.9 | 380.7 | 109.6 | 308.3 |
| 35 | 238.8 | 252.7 | 336.0 | 388.6 | 112.5 | 329.1 |
| 40 | 248.8 | 262.4 | 342.7 | 396.9 | 115.8 | 338.4 |
| 45 | 262.0 | 271.1 | 350.3 | 403.7 | 125.0 | 352.4 |
| 50 | 274.7 | 281.2 | 359.8 | 414.9 | 125.9 | 375.8 |
| 55 | 287.3 | 291.2 | 371.6 | 423.6 | 127.6 | 388.7 |
| 60 | 300.3 | 299.8 | 384.1 | 432.8 | 128.4 | 412.7 |
| 65 | 313.0 | 309.8 | 395.5 | 438.7 | 129.6 | 433.8 |
| 70 | 327.4 | 320.0 | 407.9 | 444.7 | 137.3 | 444.9 |
| 75 | 344.2 | 333.2 | 419.0 | 450.7 | 138.3 | 456.6 |
| 80 | 377.3 | 355.5 | 433.7 | 459.0 | 184.2 | 470.3 |
| 85 | 411.8 | 391.3 | 444.7 | 468.8 | 246.2 | 485.3 |
| 90 | 444.7 | 434.9 | 458.7 | 482.1 | 367.0 | 501.0 |
| 95 | 475.5 | 467.0 | 482.3 | 501.2 | 450.7 | 522.1 |
| 100 | 529.7 | 523.8 | 532.3 | 540.1 | 531.4 | 549.1 |

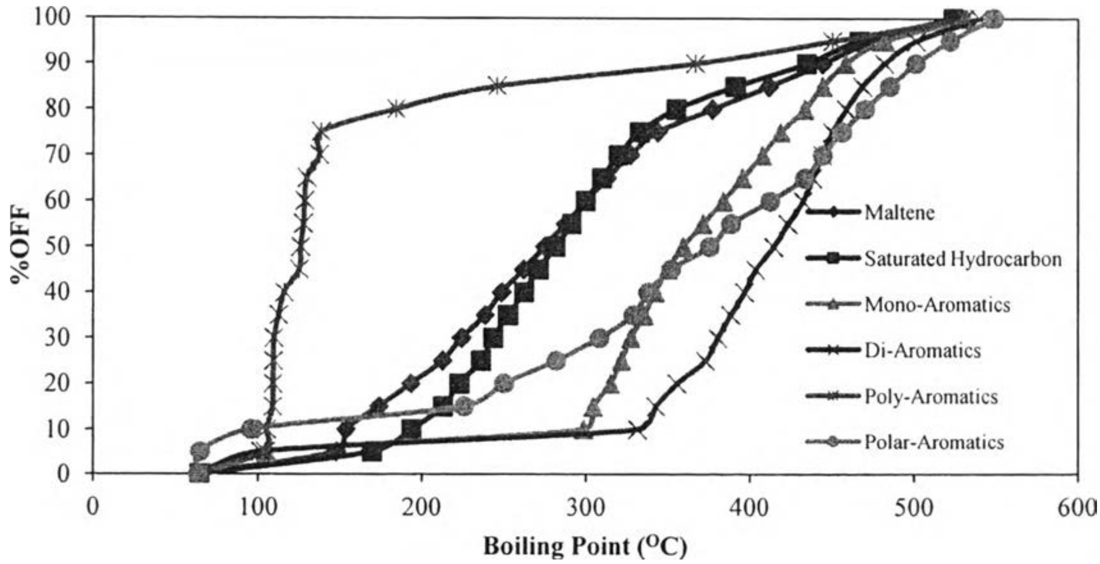



**Figure G3** True boiling point curves of 5%Ni-HBeta catalyst.

**Table G4** True boiling point curves: - 10%Ni-HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 92.9 | 92.2 | 99.2 | 90.8 | 99.1 | 99.1 |
| **5** | 175.6 | 217.2 | 100.0 | 91.8 | 99.3 | 99.2 |
| **10** | 185.7 | 244.5 | 268.8 | 92.9 | 177.7 | 99.4 |
| **15** | 206.3 | 258.9 | 293.0 | 96.0 | 246.4 | 205.3 |
| **20** | 223.1 | 271.7 | 315.8 | 140.6 | 267.7 | 243.8 |
| **25** | 239.8 | 280.4 | 335.1 | 176.9 | 287.3 | 265.5 |
| **30** | 253.8 | 286.2 | 348.4 | 408.0 | 334.9 | 277.7 |
| **35** | 266.5 | 295.4 | 372.3 | 450.6 | 387.7 | 298.2 |
| **40** | 277.8 | 302.1 | 392.6 | 465.6 | 432.4 | 317.8 |
| **45** | 285.3 | 311.3 | 411.6 | 475.6 | 443.8 | 342.6 |
| **50** | 296.4 | 319.3 | 429.2 | 483.7 | 454.7 | 385.8 |
| **55** | 306.0 | 330.7 | 436.4 | 491.7 | 464.8 | 406.4 |
| **60** | 317.9 | 340.2 | 443.8 | 497.4 | 474.2 | 429.4 |
| **65** | 333.9 | 355.7 | 450.0 | 503.8 | 483.0 | 441.8 |
| **70** | 350.6 | 375.8 | 457.2 | 508.8 | 491.7 | 453.7 |
| **75** | 381.8 | 400.7 | 464.5 | 515.2 | 498.6 | 470.1 |
| **80** | 417.8 | 428.2 | 473.5 | 522.0 | 505.3 | 486.6 |
| **85** | 441.8 | 443.5 | 481.7 | 526.1 | 514.3 | 501.8 |
| **90** | 461.0 | 460.1 | 492.5 | 532.4 | 524.2 | 517.0 |
| **95** | 488.5 | 485.6 | 505.4 | 541.7 | 534.2 | 532.6 |
| **100** | 531.3 | 528.7 | 537.8 | 557.8 | 554.7 | 558.4 |

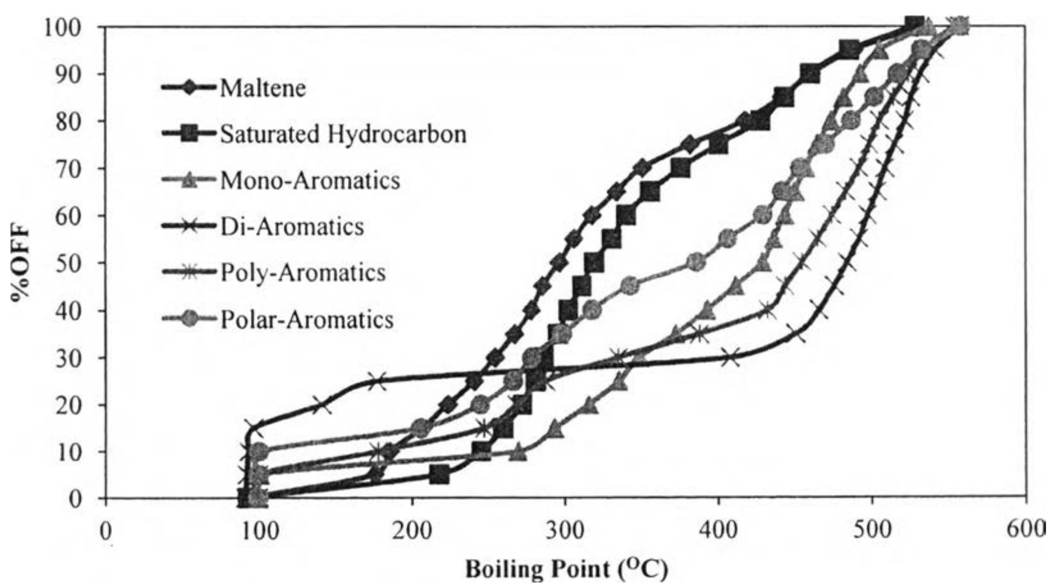



**Figure G4** True boiling point curves of 10%Ni-HBeta catalyst.

**Table G5** True boiling point curves: - 20%Ni-HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 71.4 | 86.1 | 78.4 | 45.1 | 58.8 | 46.2 |
| **5** | 148.3 | 206.5 | 231.5 | 59.5 | 214.9 | 93.8 |
| **10** | 154.9 | 230.8 | 254.7 | 86.3 | 237.5 | 140.6 |
| **15** | 172.8 | 247.5 | 265.8 | 171.1 | 254.0 | 200.4 |
| **20** | 192.4 | 256.7 | 275.2 | 230.8 | 261.4 | 234.9 |
| **25** | 211.1 | 264.1 | 284.0 | 259.0 | 277.2 | 247.1 |
| **30** | 227.1 | 273.5 | 292.1 | 282.9 | 297.2 | 269.8 |
| **35** | 239.8 | 279.1 | 300.5 | 309.2 | 323.4 | 289.7 |
| **40** | 253.2 | 288.6 | 309.2 | 338.2 | 344.1 | 313.6 |
| **45** | 260.7 | 294.7 | 316.9 | 364.7 | 356.6 | 335.3 |
| **50** | 271.4 | 303.3 | 325.7 | 386.9 | 372.1 | 350.8 |
| **55** | 279.4 | 310.6 | 334.4 | 404.7 | 381.9 | 359.3 |
| **60** | 290.5 | 318.3 | 344.1 | 419.9 | 394.9 | 373.4 |
| **65** | 299.7 | 328.3 | 356.5 | 432.2 | 405.8 | 383.6 |
| **70** | 311.2 | 338.7 | 367.4 | 444.3 | 419.2 | 397.0 |
| **75** | 323.7 | 351.8 | 379.8 | 455.4 | 432.1 | 413.3 |
| **80** | 337.7 | 367.2 | 392.4 | 466.5 | 446.4 | 432.2 |
| **85** | 357.1 | 383.4 | 413.2 | 475.1 | 462.5 | 449.5 |
| **90** | 379.7 | 404.1 | 442.5 | 484.6 | 477.3 | 468.9 |
| **95** | 415.1 | 447.5 | 490.3 | 501.1 | 499.2 | 490.0 |
| **100** | 546.1 | 557.8 | 568.9 | 544.1 | 552.0 | 555.2 |

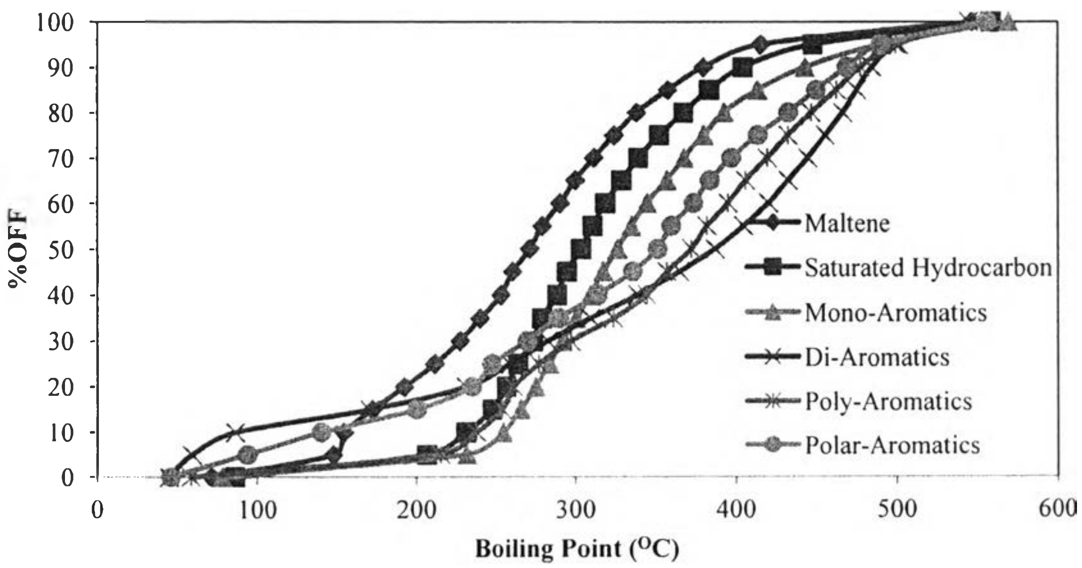



**Figure G5** True boiling point curves of 20%Ni-HBeta catalyst.

**Table G6** True boiling point curves: - HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 53.8 | 61.8 | 55.3 | 51.0 | 53.1 | 52.1 |
| **5** | 106.4 | 191.3 | 62.7 | 59.7 | 63.3 | 62.9 |
| **10** | 147.6 | 221.3 | 65.6 | 62.0 | 67.3 | 66.5 |
| **15** | 148.3 | 236.0 | 68.2 | 63.7 | 71.7 | 70.0 |
| **20** | 155.1 | 248.5 | 70.1 | 65.6 | 86.1 | 94.5 |
| **25** | 172.2 | 255.9 | 73.3 | 67.1 | 110.6 | 219.6 |
| **30** | 189.5 | 262.8 | 76.5 | 69.5 | 244.3 | 295.4 |
| **35** | 205.5 | 272.3 | 79.4 | 72.5 | 263.5 | 350.0 |
| **40** | 222.2 | 281.4 | 79.9 | 78.7 | 311.7 | 371.5 |
| **45** | 235.0 | 293.4 | 80.7 | 80.0 | 358.1 | 386.1 |
| **50** | 248.4 | 306.2 | 86.7 | 93.8 | 380.7 | 409.2 |
| **55** | 257.1 | 317.2 | 88.6 | 97.0 | 400.4 | 428.3 |
| **60** | 267.5 | 328.9 | 98.1 | 110.4 | 421.5 | 444.0 |
| **65** | 278.6 | 344.1 | 110.5 | 482.1 | 438.8 | 458.8 |
| **70** | 294.7 | 361.4 | 434.6 | 496.4 | 455.6 | 469.3 |
| **75** | 313.4 | 378.2 | 470.5 | 515.1 | 470.1 | 480.5 |
| **80** | 331.1 | 394.9 | 494.7 | 527.0 | 484.1 | 494.5 |
| **85** | 355.5 | 417.9 | 522.2 | 535.8 | 499.7 | 519.5 |
| **90** | 379.5 | 444.8 | 535.5 | 547.1 | 524.9 | 531.9 |
| **95** | 410.5 | 481.8 | 554.8 | 562.6 | 542.9 | 550.4 |
| **100** | 510.5 | 563.9 | 589.3 | 591.3 | 582.2 | 586.5 |

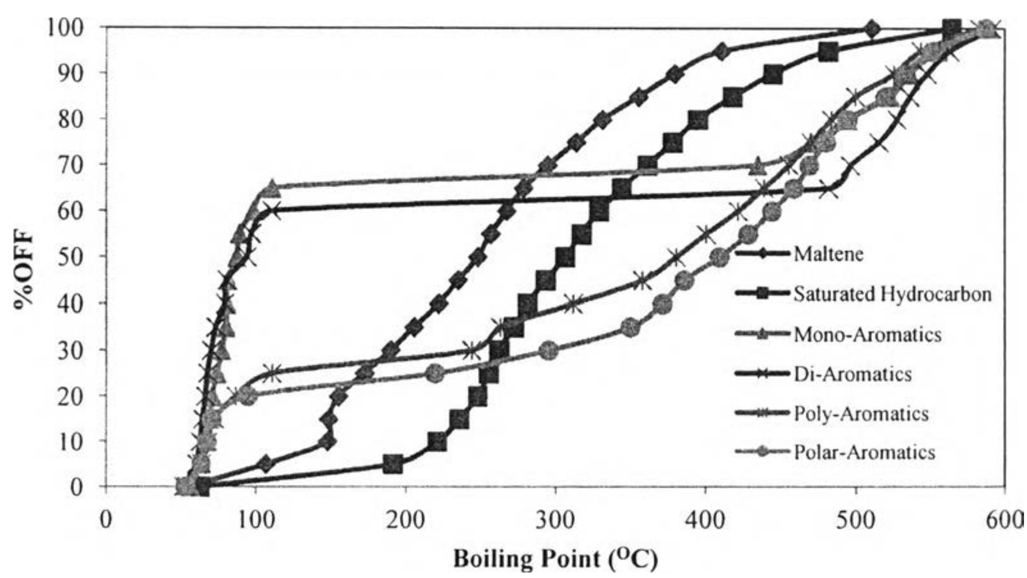



**Figure G6** True boiling point curves of HMOR catalyst.

**Table G7** True boiling point curves: - 1%Pd/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 52.5 | 61.4 | 58.2 | 47.2 | 56.5 | 37.3 |
| 5 | 70.5 | 169.1 | 63.1 | 58.2 | 59.3 | 59.5 |
| 10 | 122.9 | 203.9 | 66.9 | 59.7 | 61.2 | 61.8 |
| 15 | 147.9 | 222.7 | 70.8 | 61.0 | 62.9 | 63.9 |
| 20 | 153.9 | 238.4 | 226.8 | 62.2 | 64.3 | 65.8 |
| 25 | 169.7 | 250.7 | 287.9 | 63.3 | 66.0 | 69.2 |
| 30 | 187.4 | 257.5 | 316.2 | 64.3 | 69.2 | 92.1 |
| 35 | 206.8 | 268.0 | 333.1 | 65.4 | 74.0 | 163.3 |
| 40 | 225.0 | 276.0 | 346.6 | 66.7 | 93.8 | 233.7 |
| 45 | 241.5 | 287.4 | 357.5 | 69.0 | 109.1 | 236.2 |
| 50 | 254.3 | 296.6 | 365.5 | 70.1 | 372.6 | 293.2 |
| 55 | 265.0 | 308.6 | 374.3 | 77.9 | 407.6 | 356.5 |
| 60 | 277.0 | 318.8 | 382.1 | 92.8 | 429.9 | 409.6 |
| 65 | 292.1 | 330.2 | 388.5 | 94.9 | 466.9 | 455.6 |
| 70 | 307.8 | 345.2 | 398.3 | 404.6 | 492.5 | 482.9 |
| 75 | 322.5 | 363.1 | 409.3 | 498.1 | 509.8 | 499 |
| 80 | 339.0 | 382.0 | 426.8 | 517.8 | 525.7 | 521.5 |
| 85 | 360.5 | 405.8 | 459.0 | 528.5 | 534.8 | 530.9 |
| 90 | 383.0 | 438.0 | 497.8 | 538.6 | 546.2 | 542.9 |
| 95 | 419.0 | 476.1 | 532.4 | 553.9 | 562 | 559.8 |
| 100 | 510.0 | 546.8 | 575.8 | 587.9 | 589.3 | 589.5 |

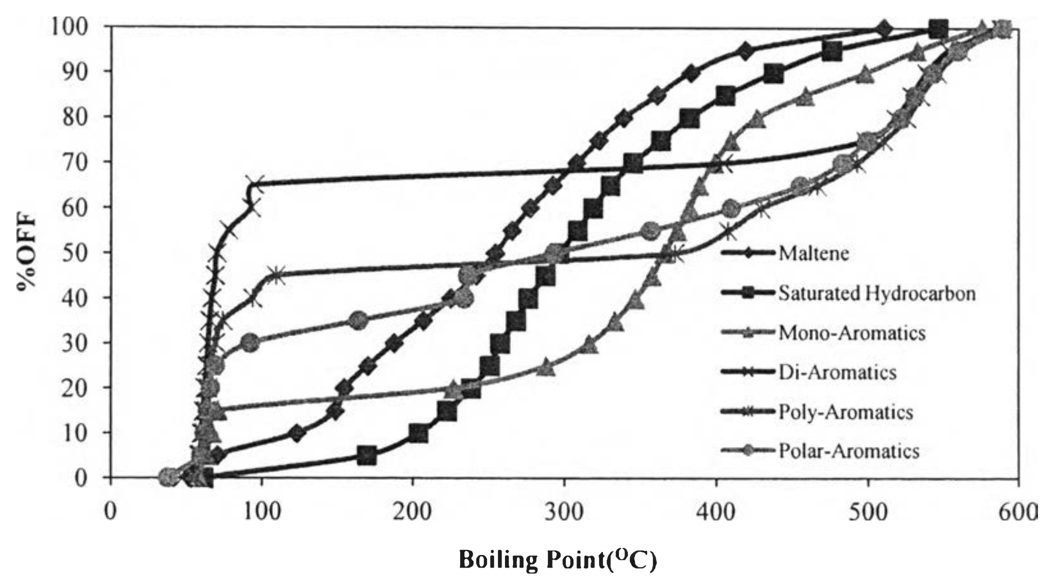



**Figure G7** True boiling point curves of 1%Pd/HMOR catalyst.

**Table G8** True boiling point curves: - 5%Ni/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 45.5 | 148.1 | 123.6 | 59.9 | 174.4 | 174.2 |
| 5 | 122.7 | 200.2 | 238.0 | 234.8 | 215.1 | 215.9 |
| 10 | 148.3 | 223.7 | 258.3 | 249.3 | 231.6 | 234.8 |
| 15 | 160.1 | 239.6 | 277.8 | 256.8 | 246.1 | 235.8 |
| 20 | 178.7 | 251.1 | 301.1 | 265.8 | 256.4 | 252.6 |
| 25 | 195.4 | 257.8 | 320.6 | 275.2 | 268.6 | 269.8 |
| 30 | 216.3 | 266.6 | 341.2 | 292.8 | 283.5 | 281.4 |
| 35 | 230.9 | 274.2 | 357.0 | 333.4 | 315.5 | 301.4 |
| 40 | 246.0 | 283.7 | 368.4 | 369.3 | 351.7 | 317.9 |
| 45 | 256.0 | 292.8 | 377.8 | 388.3 | 379.6 | 336.3 |
| 50 | 267.5 | 303.2 | 384.8 | 400.6 | 399.4 | 352.3 |
| 55 | 279.2 | 311.8 | 390.3 | 414.1 | 415.0 | 364.8 |
| 60 | 294.8 | 320.4 | 398.8 | 423.0 | 425.7 | 380.7 |
| 65 | 312.1 | 329.4 | 406.8 | 431.6 | 436.4 | 393.7 |
| 70 | 328.3 | 341.2 | 416.8 | 440.0 | 446.0 | 414.4 |
| 75 | 348.7 | 355.4 | 426.6 | 448.8 | 456.1 | 437.1 |
| 80 | 371.0 | 369.5 | 437.3 | 460.2 | 467.2 | 461.9 |
| 85 | 392.4 | 384.3 | 450.3 | 471.7 | 477.0 | 481.1 |
| 90 | 422.3 | 403.5 | 467.4 | 484.9 | 492.1 | 502.1 |
| 95 | 458.2 | 437.8 | 486.1 | 513.6 | 526.1 | 532.3 |
| 100 | 533.9 | 531.9 | 547.5 | 562.7 | 571.5 | 577.9 |

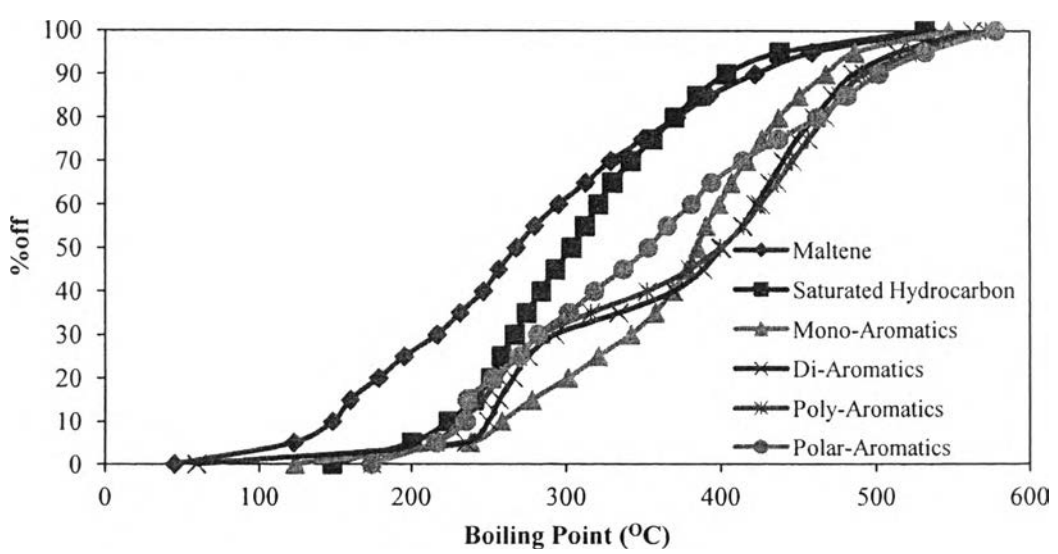



**Figure G8** True boiling point curves of 5%Ni/HMOR catalyst.

**Table G9** True boiling point curves: - 10%Ni/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 56.3 | 108.2 | 77.8 | 57.8 | 94.1 | 52.1 |
| **5** | 148.8 | 194.7 | 247.4 | 59.7 | 111.0 | 127.3 |
| **10** | 159.9 | 224.0 | 271.1 | 62.2 | 112.2 | 144.0 |
| **15** | 185.7 | 241.5 | 289.8 | 93.7 | 127.2 | 177.5 |
| **20** | 211.3 | 254.7 | 307.1 | 94.8 | 128.7 | 218.4 |
| **25** | 229.6 | 262.2 | 318.6 | 124.2 | 130.5 | 235.5 |
| **30** | 247.3 | 272.6 | 332.6 | 146.5 | 136.5 | 255.4 |
| **35** | 257.4 | 282.0 | 346.0 | 186.9 | 166.0 | 277.8 |
| **40** | 269.5 | 292.6 | 360.2 | 235.7 | 212.8 | 295.1 |
| **45** | 279.8 | 303.4 | 371.3 | 271.0 | 236.8 | 316.6 |
| **50** | 293.3 | 312.1 | 384.3 | 311.5 | 254.3 | 335.6 |
| **55** | 306.6 | 321.4 | 396.2 | 347.5 | 273.4 | 349.7 |
| **60** | 317.9 | 330.0 | 408.7 | 374.0 | 313.4 | 359.6 |
| **65** | 329.5 | 341.2 | 421.3 | 397.2 | 352.3 | 373.8 |
| **70** | 342.9 | 353.3 | 431.0 | 416.0 | 378.2 | 384.4 |
| **75** | 358.5 | 366.3 | 442.4 | 433.5 | 400.4 | 402.6 |
| **80** | 373.5 | 378.6 | 453.8 | 449.8 | 423.3 | 426.0 |
| **85** | 389.2 | 391.7 | 468.6 | 466.7 | 446.6 | 453.5 |
| **90** | 412.4 | 412.4 | 483.3 | 480.6 | 471.2 | 481.7 |
| **95** | 453.0 | 446.8 | 516.0 | 512.9 | 497.5 | 523.1 |
| **100** | 548.2 | 539.6 | 566.9 | 571.9 | 557.5 | 568.5 |

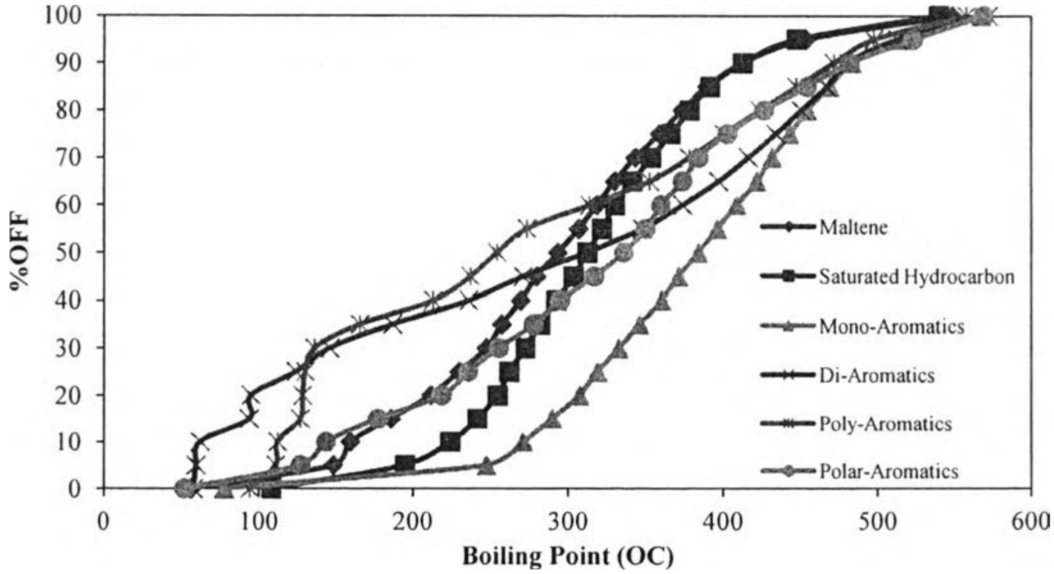



**Figure G9** True boiling point curves of 10%Ni/HMOR catalyst.

**Table G10** True boiling point curves: - 20%Ni/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 69.7 | 76.7 | 69.2 | 58.2 | 93.8 | 69.2 |
| **5** | 143.2 | 160.7 | 80.7 | 86.1 | 106.3 | 130.9 |
| **10** | 148.8 | 191.3 | 246.9 | 351.9 | 275.0 | 174.0 |
| **15** | 160.1 | 213.9 | 267.5 | 367.2 | 311.5 | 205.0 |
| **20** | 178.9 | 228.2 | 283.5 | 375.9 | 343.8 | 234.3 |
| **25** | 196.2 | 243.2 | 299.3 | 381.4 | 363.2 | 243.5 |
| **30** | 219.6 | 253.4 | 313.5 | 388.0 | 374.3 | 266.4 |
| **35** | 234.5 | 260.2 | 325.8 | 393.8 | 389.3 | 284.0 |
| **40** | 250.3 | 269.9 | 336.0 | 400.5 | 398.8 | 308.5 |
| **45** | 259.9 | 278.1 | 346.9 | 406.0 | 408.2 | 328.5 |
| **50** | 272.8 | 289.6 | 357.0 | 414.0 | 417.4 | 349.8 |
| **55** | 286.9 | 301.4 | 363.9 | 421.4 | 423.9 | 366.6 |
| **60** | 302.7 | 313.3 | 372.4 | 427.5 | 431.9 | 383.5 |
| **65** | 317.9 | 326.5 | 379.2 | 435.5 | 439.8 | 402.1 |
| **70** | 335.5 | 340.9 | 385.6 | 444.3 | 447.7 | 421.4 |
| **75** | 356.9 | 360.0 | 391.5 | 454.8 | 456.8 | 439.6 |
| **80** | 376.2 | 379.6 | 400.8 | 467.7 | 466.8 | 460.0 |
| **85** | 394.9 | 401.3 | 413.1 | 476.7 | 475.5 | 478.1 |
| **90** | 421.9 | 431.4 | 431.8 | 489.2 | 487.5 | 496.7 |
| **95** | 459.0 | 468.0 | 483.2 | 513.7 | 518.2 | 529.0 |
| **100** | 537.1 | 527.7 | 559.4 | 548.0 | 564.1 | 569.6 |

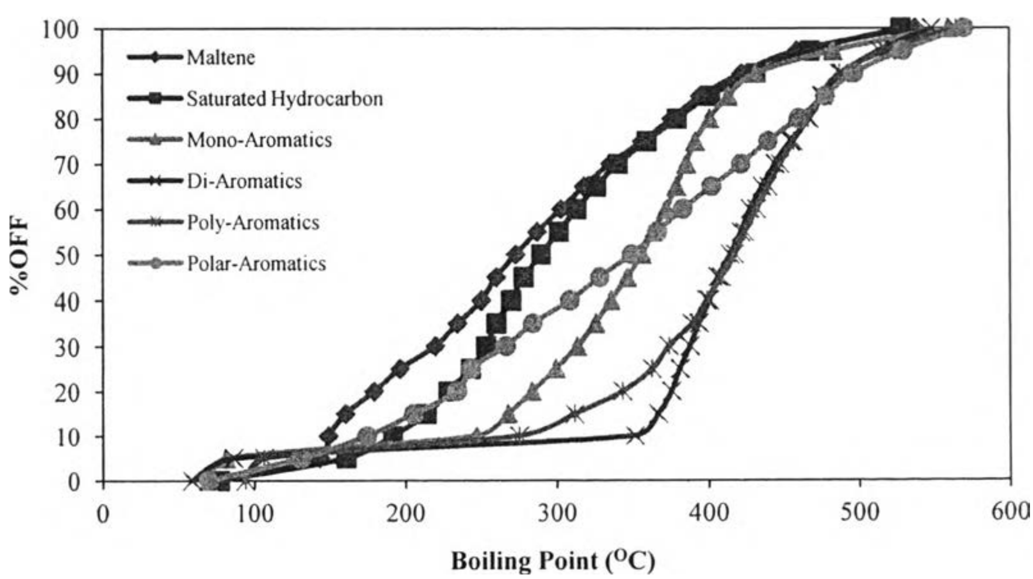



**Figure G10** True boiling point curves of 20%Ni/HMOR catalyst.

**Table G11** True boiling point curves: - 1%Ru/HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 56.5 | 57.6 | 51.4 | 50.8 | 56.1 | 42.1 |
| **5** | 109.0 | 133.3 | 55.0 | 53.8 | 80.9 | 53.3 |
| **10** | 133.2 | 148.3 | 58.0 | 56.3 | 96.5 | 55.0 |
| **15** | 141.5 | 160.6 | 61.0 | 58.4 | 164.7 | 56.7 |
| **20** | 154.7 | 171.6 | 84.5 | 64.8 | 228.9 | 58.2 |
| **25** | 170.2 | 183.2 | 183.3 | 234.9 | 253.3 | 60.8 |
| **30** | 186.9 | 195.8 | 215.1 | 242.9 | 274.6 | 82.2 |
| **35** | 201.6 | 204.0 | 233.5 | 259.3 | 285.5 | 223.2 |
| **40** | 215.5 | 212.3 | 241.7 | 264.7 | 300.8 | 301.0 |
| **45** | 225.7 | 220.8 | 243.7 | 270.0 | 314.9 | 327.5 |
| **50** | 239.5 | 229.1 | 246.0 | 279.4 | 335.5 | 343.5 |
| **55** | 256.7 | 238.2 | 262.0 | 288.0 | 390.0 | 354.5 |
| **60** | 275.9 | 251.1 | 266.5 | 297.1 | 391.0 | 367.2 |
| **65** | 294.3 | 266.3 | 276.8 | 305.1 | 424.3 | 377.5 |
| **70** | 315.7 | 283.7 | 285.2 | 315.9 | 444.9 | 392.1 |
| **75** | 339.9 | 301.1 | 299.2 | 327.8 | 466.6 | 416.0 |
| **80** | 390.8 | 329.7 | 313.3 | 343.6 | 484.9 | 447.6 |
| **85** | 440.7 | 390.7 | 331.6 | 365.2 | 500.4 | 486.2 |
| **90** | 480.1 | 446.5 | 363.2 | 394.5 | 516.3 | 517.2 |
| **95** | 512.0 | 494.2 | 509.1 | 524.1 | 533.9 | 540.5 |
| **100** | 559.4 | 553.0 | 574.7 | 576.0 | 568.0 | 581.7 |

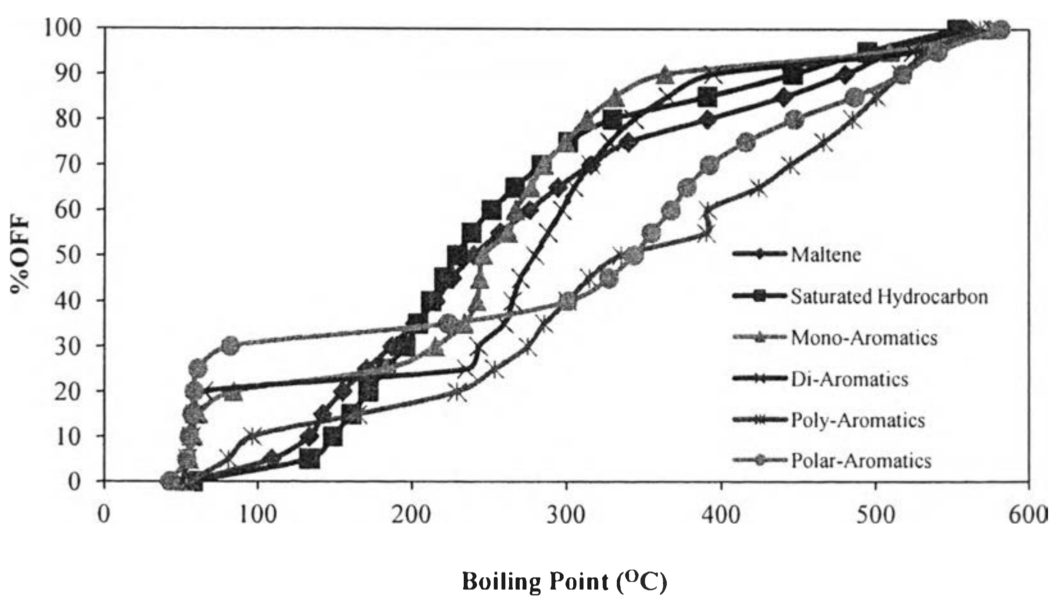



**Figure G11** True boiling point curves of 1%Ru/HBeta catalyst.

**Table G12** True boiling point curves: - 5%Fe/HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 55.5 | 65.6 | 59.9 | 62.2 | 61.6 | 63.5 |
| 5 | 72.0 | 96.5 | 62.9 | 64.3 | 64.3 | 66.3 |
| 10 | 123.5 | 171.9 | 65 | 65.8 | 66.3 | 68.4 |
| 15 | 148.2 | 192.9 | 66.9 | 67.1 | 68.2 | 69.5 |
| 20 | 148.6 | 211.8 | 68.6 | 68.4 | 69.3 | 69.9 |
| 25 | 154.9 | 223.7 | 69.5 | 69.2 | 69.8 | 70.6 |
| 30 | 165.9 | 233.7 | 71.3 | 69.8 | 70.5 | 72.1 |
| 35 | 179.0 | 246.1 | 87.1 | 70.3 | 72.0 | 98.3 |
| 40 | 193.2 | 254.2 | 97.8 | 71.5 | 98.1 | 218.8 |
| 45 | 208.5 | 258.5 | 223.3 | 79.9 | 102.4 | 237 |
| 50 | 223.9 | 267.8 | 490.3 | 98.5 | 345.3 | 306.7 |
| 55 | 234.8 | 275.2 | 501 | 456.7 | 496.5 | 356.7 |
| 60 | 248.9 | 287.5 | 514.5 | 472.1 | 509.3 | 414.5 |
| 65 | 256.4 | 301.7 | 524.6 | 482.9 | 522.8 | 460.6 |
| 70 | 266.6 | 317.9 | 530.1 | 491.4 | 528.3 | 478.4 |
| 75 | 278.2 | 338.4 | 536.2 | 499.9 | 534.4 | 490.9 |
| 80 | 297.6 | 364.5 | 543.1 | 513.3 | 541.4 | 503.7 |
| 85 | 327.6 | 389.8 | 551.0 | 524.4 | 549.4 | 522.4 |
| 90 | 366.9 | 426.7 | 560.6 | 531.0 | 558.9 | 530.2 |
| 95 | 488.5 | 471.9 | 573.1 | 540.6 | 571.7 | 542.6 |
| 100 | 557.7 | 546.8 | 594.0 | 562.2 | 592.5 | 572.2 |

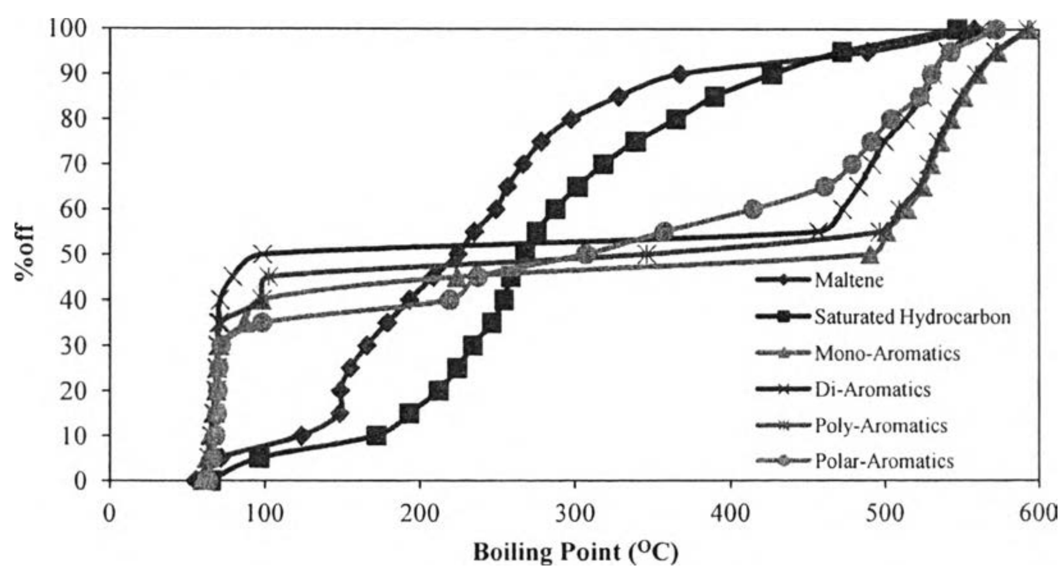



**Figure G12** True boiling point curves of 5%Fe/HBeta catalyst.

**Table G13** True boiling point curves: - 10%Fe/HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 55.6 | 62.8 | 58.2 | 55.7 | 55.7 | 55.5 |
| 5 | 106.6 | 140.9 | 103.8 | 63.5 | 93.9 | 99.0 |
| 10 | 136.9 | 162.5 | 134.7 | 65.6 | 133.6 | 134.3 |
| 15 | 138.3 | 180.0 | 149.1 | 70.3 | 149.5 | 149.7 |
| 20 | 149.9 | 198.5 | 169.8 | 77.7 | 172.7 | 170.9 |
| 25 | 163.1 | 209.5 | 192.6 | 96.4 | 199.8 | 195.1 |
| 30 | 177.2 | 223.2 | 212.6 | 133.5 | 224.4 | 214.9 |
| 35 | 194.1 | 231.9 | 232.0 | 151.4 | 248.8 | 237.0 |
| 40 | 205.3 | 245.0 | 252.6 | 179.8 | 269.9 | 258.8 |
| 45 | 217.9 | 257.1 | 271.9 | 210.1 | 288.1 | 279.1 |
| 50 | 227.9 | 268.7 | 289.6 | 239.1 | 305.9 | 297.5 |
| 55 | 241.1 | 281.4 | 306.5 | 267.2 | 321.0 | 314.4 |
| 60 | 252.7 | 293.4 | 323.4 | 292.0 | 337.6 | 330.6 |
| 65 | 267.3 | 304.9 | 340.2 | 314.8 | 390.1 | 389.8 |
| 70 | 281.5 | 319.0 | 390.3 | 337.3 | 390.9 | 390.6 |
| 75 | 295.9 | 334.3 | 397.5 | 390.4 | 411.2 | 405.7 |
| 80 | 311.5 | 390.0 | 425.7 | 407.5 | 433.0 | 431.4 |
| 85 | 333.0 | 392.9 | 442.4 | 436.0 | 445.0 | 444.0 |
| 90 | 390.4 | 435.9 | 456.7 | 452.5 | 457.7 | 457.2 |
| 95 | 438.1 | 469.0 | 472.0 | 470.0 | 472.2 | 471.8 |
| 100 | 532.7 | 528.4 | 492.1 | 492.8 | 492.4 | 492.2 |

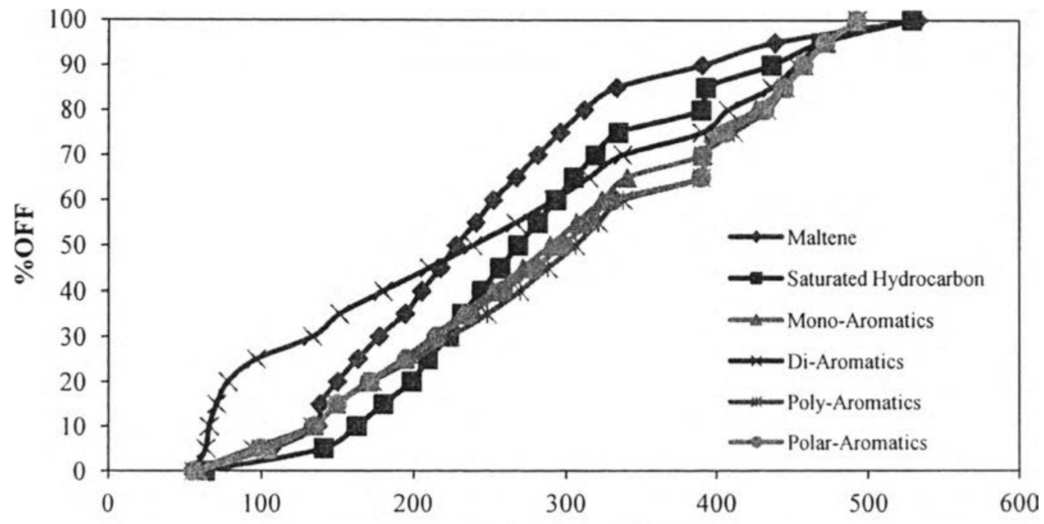



**Figure G13** True boiling point curves of 10%Fe/HBeta catalyst.

**Table G14** True boiling point curves: - 20%Fe/HBeta catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 56.3 | 56.5 | 55.9 | 50.4 | 55.8 | 55.7 |
| 5 | 69.8 | 65.4 | 56.6 | 53.8 | 56.6 | 56.4 |
| 10 | 124.9 | 148.8 | 57.2 | 55.5 | 57.2 | 56.9 |
| 15 | 135.2 | 172.8 | 57.7 | 56.7 | 57.7 | 57.3 |
| 20 | 149.9 | 195.7 | 58.1 | 58.0 | 58.3 | 57.7 |
| 25 | 169.7 | 207.3 | 58.4 | 60.1 | 58.7 | 58.1 |
| 30 | 189.0 | 221.1 | 58.7 | 61.2 | 60.7 | 58.4 |
| 35 | 204.2 | 230.2 | 60.1 | 62.9 | 75.7 | 58.7 |
| 40 | 219.0 | 243.2 | 65.8 | 72.8 | 76.9 | 60.1 |
| 45 | 228.0 | 258.5 | 75.4 | 86.1 | 196.4 | 75.1 |
| 50 | 242.4 | 273.4 | 76.2 | 87.4 | 219.0 | 76.0 |
| 55 | 257.7 | 286.0 | 78.9 | 90.1 | 247.9 | 77.0 |
| 60 | 272.8 | 299.8 | 431.0 | 212.2 | 310.2 | 200.8 |
| 65 | 286.0 | 315.7 | 450.2 | 230.7 | 389.9 | 212.5 |
| 70 | 299.8 | 333.2 | 459.1 | 249.0 | 410.9 | 258.6 |
| 75 | 316.3 | 390.0 | 468.4 | 455.9 | 445.3 | 320.6 |
| 80 | 334.8 | 393.0 | 482.8 | 490.4 | 463.8 | 458.2 |
| 85 | 390.2 | 432.1 | 505.6 | 512.8 | 498.0 | 507.3 |
| 90 | 411.6 | 454.3 | 524.7 | 530.9 | 517.9 | 525.5 |
| 95 | 462.2 | 482.6 | 547.8 | 549.5 | 536.7 | 542.3 |
| 100 | 548.7 | 547.1 | 574.3 | 586.1 | 571.0 | 573.9 |

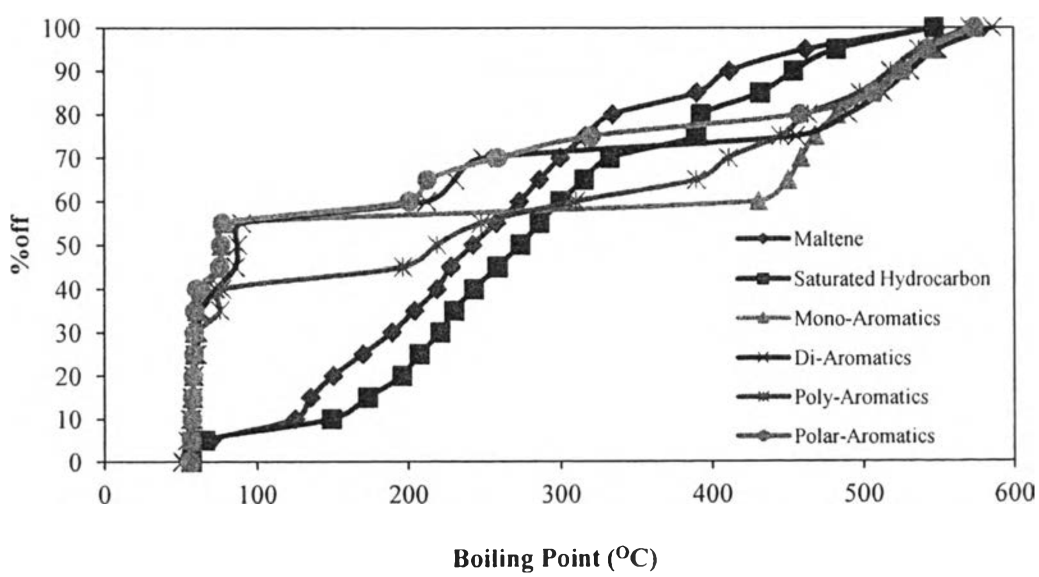



**Figure G14** True boiling point curves of 20%Fe/HBeta catalyst.

**Table G15** True boiling point curves: - 1%Ru/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 55.4 | 55.5 | 55.7 | 54.1 | 55.4 | 53.8 |
| 5 | 58.0 | 57.6 | 64.2 | 55.7 | 56.4 | 55.7 |
| 10 | 103.7 | 131.8 | 170.0 | 56.2 | 57.6 | 56.2 |
| 15 | 131.8 | 152.6 | 209.1 | 56.8 | 74.7 | 56.7 |
| 20 | 140.1 | 168.6 | 221.9 | 57.3 | 79.7 | 57.2 |
| 25 | 150.9 | 181.8 | 230.8 | 57.8 | 86.8 | 57.7 |
| 30 | 168.1 | 194.9 | 237.7 | 73.0 | 93.7 | 59.3 |
| 35 | 186.4 | 202.7 | 244.9 | 131.3 | 131.5 | 73.9 |
| 40 | 200.3 | 211.3 | 251.2 | 174.8 | 159.1 | 206.2 |
| 45 | 213.0 | 219.1 | 257.2 | 222.4 | 178.7 | 247.3 |
| 50 | 222.9 | 224.8 | 264.4 | 268.2 | 200.5 | 288.1 |
| 55 | 233.9 | 231.5 | 274.3 | 282.9 | 224.9 | 301.2 |
| 60 | 246.5 | 240.9 | 281.9 | 297.8 | 269.7 | 315.5 |
| 65 | 263.1 | 252.4 | 284.1 | 308.1 | 283.2 | 323.0 |
| 70 | 280.2 | 263.2 | 293.9 | 319.7 | 303.9 | 335.2 |
| 75 | 296.1 | 276.2 | 302.7 | 332.1 | 313.5 | 389.8 |
| 80 | 318.8 | 288.8 | 313.5 | 389.7 | 329.4 | 390.6 |
| 85 | 343.9 | 302.1 | 329.2 | 390.6 | 389.8 | 439.1 |
| 90 | 402.1 | 326.7 | 389.8 | 503.7 | 391.0 | 515.4 |
| 95 | 456.2 | 390.5 | 407.9 | 534.1 | 460.4 | 537.2 |
| 100 | 553.8 | 554.6 | 549.6 | 570.4 | 560.9 | 570.8 |

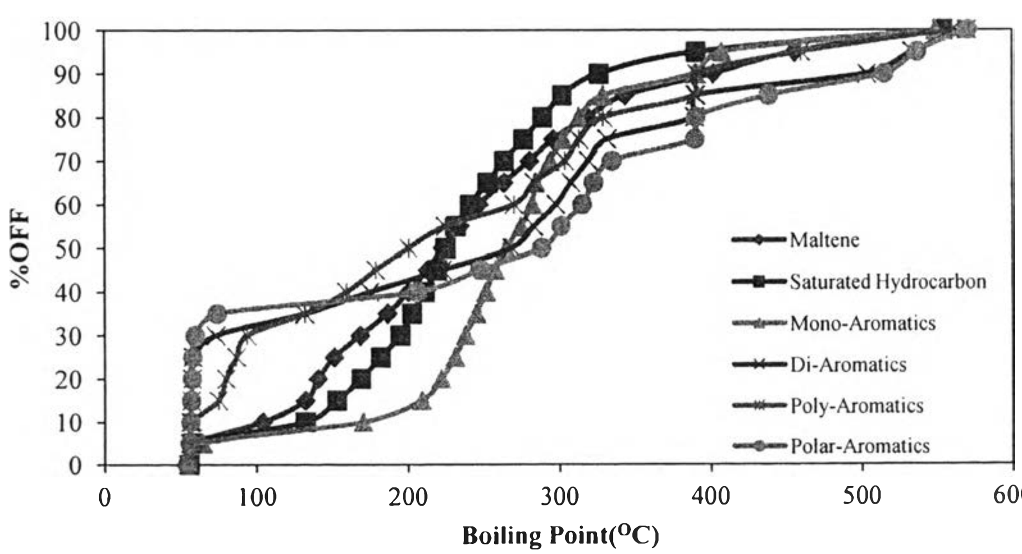



**Figure G15** True boiling point curves of 1%Ru/HMOR catalyst.

**Table G16** True boiling point curves: - 5%Fe/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| **0** | 52.1 | 50.6 | 55 | 57.7 | 50.2 | 52.1 |
| **5** | 60.5 | 52.7 | 98.7 | 60.1 | 52.3 | 60.5 |
| **10** | 138.9 | 54.2 | 139.5 | 88.5 | 54.0 | 138.9 |
| **15** | 163.2 | 55.7 | 163.0 | 128.4 | 55.3 | 163.2 |
| **20** | 181.6 | 56.7 | 193.7 | 145.2 | 56.5 | 181.6 |
| **25** | 204.0 | 58.0 | 218.6 | 164.8 | 57.8 | 204.0 |
| **30** | 215.2 | 59.1 | 244.5 | 190.3 | 58.8 | 215.2 |
| **35** | 231.6 | 62.4 | 274.0 | 214.7 | 61.4 | 231.6 |
| **40** | 241.1 | 72.6 | 302.1 | 239.2 | 84.0 | 241.1 |
| **45** | 249.2 | 84.6 | 329.6 | 265.0 | 193.4 | 249.2 |
| **50** | 259.7 | 138.9 | 390.3 | 289.6 | 222.3 | 259.7 |
| **55** | 269.7 | 490.6 | 403.9 | 312.8 | 239.7 | 269.7 |
| **60** | 281.7 | 502.5 | 429.6 | 336.7 | 371.5 | 281.7 |
| **65** | 294.2 | 517.9 | 440.7 | 390.5 | 497.5 | 294.2 |
| **70** | 304.8 | 526.4 | 450.9 | 412.0 | 513.6 | 304.8 |
| **75** | 315.8 | 532.7 | 460.9 | 438.9 | 525.5 | 315.8 |
| **80** | 330.6 | 539.9 | 471.6 | 455.0 | 532.8 | 330.6 |
| **85** | 349.3 | 548.2 | 484.0 | 470.4 | 541.4 | 349.3 |
| **90** | 369.9 | 558.1 | 498.2 | 486.0 | 552.1 | 369.9 |
| **95** | 399.8 | 571.2 | 519.8 | 506.8 | 566.4 | 399.8 |
| **100** | 526.4 | 593.0 | 549.9 | 543.7 | 591.0 | 526.4 |

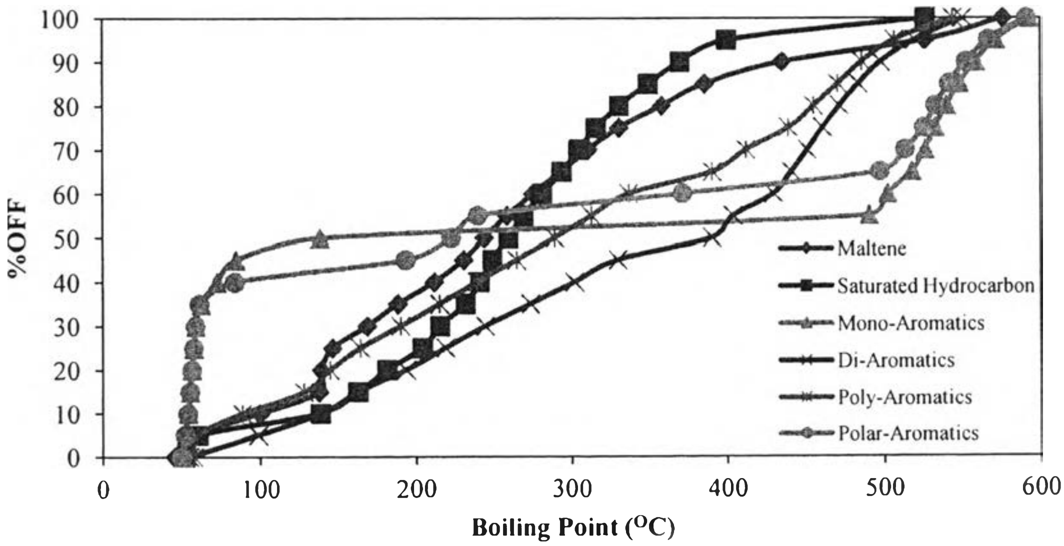



**Figure G16** True boiling point curves of 5%Fe/HMOR catalyst.

**Table G17** True boiling point curves: - 10%Fe/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 58.0 | 56.1 | 55.7 | 58.0 | 55.4 | 55.3 |
| 5 | 103.2 | 59.3 | 56.4 | 58.4 | 56.1 | 55.9 |
| 10 | 131.2 | 140.3 | 56.9 | 58.7 | 56.5 | 56.3 |
| 15 | 133.4 | 161.5 | 57.5 | 74.8 | 56.9 | 56.7 |
| 20 | 141.6 | 181.1 | 57.9 | 152.0 | 57.2 | 57.0 |
| 25 | 155.0 | 196.4 | 58.5 | 215.9 | 57.6 | 57.3 |
| 30 | 170.3 | 206.8 | 60.8 | 270.9 | 57.9 | 57.7 |
| 35 | 189.7 | 217.7 | 74.8 | 296.5 | 58.3 | 58.0 |
| 40 | 201.8 | 224.6 | 279.7 | 315.3 | 58.7 | 58.3 |
| 45 | 215.0 | 232.5 | 294.9 | 328.0 | 60.5 | 58.7 |
| 50 | 224.1 | 242.2 | 306.8 | 389.8 | 74.5 | 59.7 |
| 55 | 234.7 | 254.6 | 321.4 | 390.4 | 82.0 | 73.8 |
| 60 | 246.9 | 264.1 | 330.8 | 397.7 | 317.8 | 206.8 |
| 65 | 262.1 | 276.9 | 343.0 | 432.0 | 390.0 | 503.3 |
| 70 | 277.3 | 287.4 | 390.3 | 451.0 | 501.8 | 512.2 |
| 75 | 291.5 | 298.8 | 492.6 | 469.1 | 512.4 | 522.6 |
| 80 | 307.7 | 315.6 | 509.8 | 488.3 | 523.8 | 528.9 |
| 85 | 330.5 | 337.2 | 524.3 | 504.4 | 531.8 | 536.4 |
| 90 | 390.6 | 390.7 | 535.0 | 523.4 | 541.7 | 545.6 |
| 95 | 450.6 | 490.0 | 549.0 | 539.4 | 555.1 | 557.9 |
| 100 | 537.4 | 560.0 | 575.4 | 574.5 | 577.8 | 578.9 |

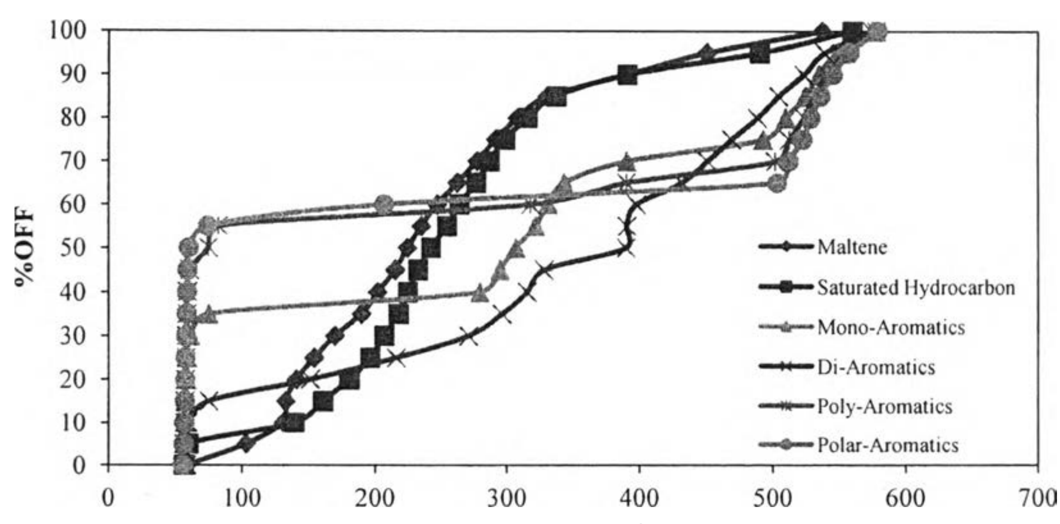



**Figure G17** True boiling point curves of 10%Fe/HMOR catalyst.

**Table G18** True boiling point curves: - 20%Fe/HMOR catalyst

| % OFF | Boiling point (°C) | | | | | |
|---|---|---|---|---|---|---|
| | Maltene | Saturated Hydrocarbons | Mono-aromatics | Di-aromatics | Poly-aromatics | Polar-aromatics |
| 0 | 58.3 | 62.0 | 58.1 | 58.1 | 58.1 | 58.1 |
| 5 | 104.6 | 131.0 | 75.3 | 140.3 | 60.8 | 74.1 |
| 10 | 131.8 | 140.1 | 147.6 | 171.4 | 78.9 | 183.3 |
| 15 | 140.2 | 152.5 | 171.3 | 194.7 | 87.6 | 207.0 |
| 20 | 147.8 | 164.0 | 194.7 | 205.6 | 95.8 | 230.8 |
| 25 | 159.9 | 175.1 | 209.9 | 221.3 | 223.7 | 260.2 |
| 30 | 175.5 | 188.6 | 221.9 | 238.6 | 270.5 | 279.4 |
| 35 | 194.7 | 197.1 | 233.2 | 258.6 | 285.3 | 296.3 |
| 40 | 206.3 | 206.0 | 238.3 | 275.4 | 303.2 | 308.9 |
| 45 | 218.4 | 215.5 | 248.2 | 285.1 | 311.3 | 319.7 |
| 50 | 227.9 | 222.8 | 256.9 | 297.0 | 324.9 | 328.5 |
| 55 | 240.9 | 230.0 | 269.7 | 304.6 | 335.2 | 339.7 |
| 60 | 256.8 | 241.5 | 279.6 | 311.9 | 389.8 | 390.0 |
| 65 | 272.7 | 255.8 | 283.7 | 322.0 | 390.3 | 390.6 |
| 70 | 285.8 | 270.6 | 295.6 | 330.7 | 390.9 | 405.4 |
| 75 | 299.6 | 284.3 | 306.9 | 341.0 | 413.8 | 433.9 |
| 80 | 317.2 | 297.3 | 322.1 | 390.2 | 435.8 | 451.0 |
| 85 | 336.3 | 318.6 | 339.8 | 394.6 | 452.0 | 472.2 |
| 90 | 390.5 | 343.1 | 390.5 | 436.3 | 475.7 | 496.1 |
| 95 | 439.0 | 418.1 | 438.3 | 484.9 | 510.5 | 521.5 |
| 100 | 528.8 | 528.6 | 539.2 | 552.6 | 561.7 | 562.5 |

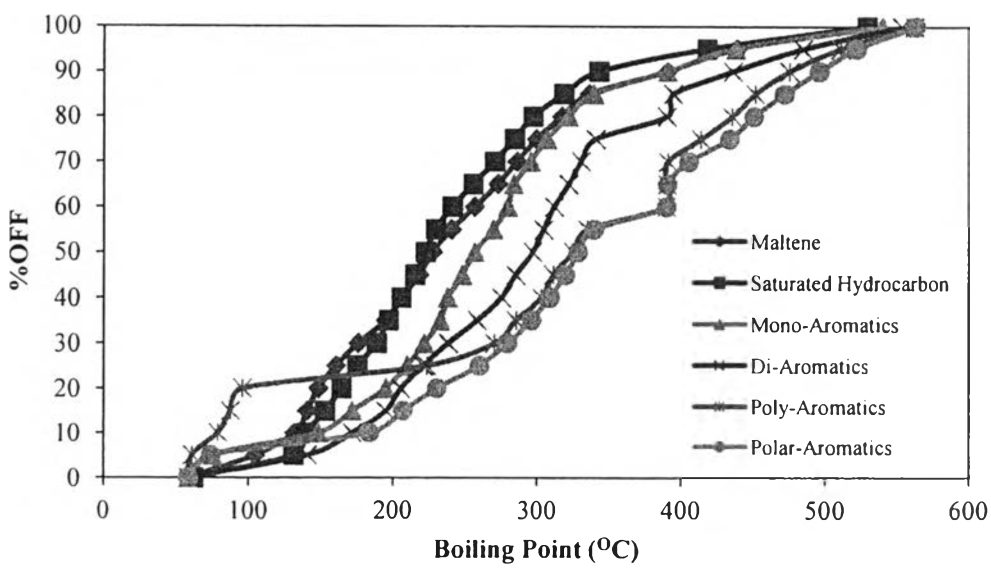



**Figure G18** True boiling point curves of 20%Fe/HMOR catalyst.

## Appendix H Carbon Number Distribution of Maltenes

**Table H1** Influences of 1%Pd/HBeta and varied Ni/HBeta

| No. carbon. | Non-catalytic | HBeta | 1%Pd/ HBeta | 5%Ni/ HBeta | 10%Ni/ HBeta | 20%Ni/ HBeta |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 | 0.008 | 0.001 | 0.000 | 0.000 |
| 4 | 0.248 | 0.080 | 0.042 | 0.011 | 0.000 | 0.019 |
| 5 | 2.099 | 1.470 | 0.172 | 0.081 | 0.001 | 0.228 |
| 6 | 2.668 | 3.952 | 0.558 | 0.364 | 0.017 | 0.480 |
| 7 | 3.301 | 6.881 | 1.431 | 1.097 | 0.161 | 0.934 |
| 8 | 3.974 | 9.068 | 2.933 | 2.386 | 0.719 | 1.665 |
| 9 | 4.650 | 9.995 | 4.896 | 4.033 | 1.913 | 2.715 |
| 10 | 5.280 | 9.829 | 6.848 | 5.629 | 3.574 | 4.034 |
| 11 | 5.811 | 8.989 | 8.284 | 6.820 | 5.243 | 5.457 |
| 12 | 6.193 | 7.854 | 8.948 | 7.452 | 6.516 | 6.744 |
| 13 | 6.390 | 6.674 | 8.875 | 7.562 | 7.226 | 7.664 |
| 14 | 6.386 | 5.581 | 8.276 | 7.281 | 7.408 | 8.088 |
| 15 | 6.193 | 4.628 | 7.391 | 6.758 | 7.197 | 8.019 |
| 16 | 5.841 | 3.826 | 6.410 | 6.117 | 6.737 | 7.560 |
| 17 | 5.378 | 3.164 | 5.456 | 5.445 | 6.152 | 6.856 |
| 18 | 4.850 | 2.623 | 4.591 | 4.795 | 5.525 | 6.040 |
| 19 | 4.302 | 2.184 | 3.840 | 4.196 | 4.909 | 5.213 |
| 20 | 3.766 | 1.828 | 3.204 | 3.660 | 4.335 | 4.438 |
| 21 | 3.265 | 1.538 | 2.675 | 3.189 | 3.815 | 3.745 |
| 22 | 2.812 | 1.302 | 2.238 | 2.781 | 3.354 | 3.145 |
| 23 | 2.411 | 1.109 | 1.879 | 2.430 | 2.950 | 2.636 |
| 24 | 2.063 | 0.951 | 1.584 | 2.128 | 2.598 | 2.210 |
| 25 | 1.763 | 0.819 | 1.341 | 1.869 | 2.293 | 1.855 |
| 26 | 1.506 | 0.710 | 1.141 | 1.647 | 2.028 | 1.561 |
| 27 | 1.289 | 0.619 | 0.975 | 1.456 | 1.799 | 1.317 |
| 28 | 1.104 | 0.541 | 0.836 | 1.291 | 1.600 | 1.114 |
| 29 | 0.947 | 0.476 | 0.720 | 1.148 | 1.426 | 0.946 |
| 30 | 0.814 | 0.420 | 0.623 | 1.023 | 1.274 | 0.806 |
| 31 | 0.700 | 0.372 | 0.540 | 0.914 | 1.141 | 0.688 |
| 32 | 0.604 | 0.330 | 0.470 | 0.818 | 1.023 | 0.589 |
| 33 | 0.521 | 0.293 | 0.410 | 0.733 | 0.918 | 0.505 |
| 34 | 0.450 | 0.261 | 0.358 | 0.658 | 0.824 | 0.434 |
| 35 | 0.389 | 0.233 | 0.313 | 0.590 | 0.740 | 0.373 |
| 36 | 0.336 | 0.207 | 0.274 | 0.529 | 0.665 | 0.321 |
| 37 | 0.291 | 0.185 | 0.240 | 0.474 | 0.596 | 0.277 |
| 38 | 0.251 | 0.164 | 0.209 | 0.424 | 0.533 | 0.238 |
| 39 | 0.216 | 0.146 | 0.183 | 0.378 | 0.476 | 0.205 |
| 40 | 0.186 | 0.129 | 0.159 | 0.336 | 0.423 | 0.176 |
| 41 | 0.160 | 0.114 | 0.138 | 0.297 | 0.374 | 0.150 |
| 42 | 0.136 | 0.100 | 0.119 | 0.260 | 0.329 | 0.128 |
| 43 | 0.115 | 0.086 | 0.101 | 0.226 | 0.286 | 0.108 |
| 44 | 0.096 | 0.074 | 0.086 | 0.194 | 0.245 | 0.090 |
| 45 | 0.079 | 0.062 | 0.071 | 0.163 | 0.206 | 0.074 |
| 46 | 0.063 | 0.050 | 0.057 | 0.132 | 0.167 | 0.059 |
| 47 | 0.048 | 0.039 | 0.044 | 0.102 | 0.130 | 0.045 |
| 48 | 0.033 | 0.027 | 0.031 | 0.072 | 0.091 | 0.031 |
| 49 | 0.019 | 0.016 | 0.017 | 0.041 | 0.052 | 0.018 |
| 50 | 0.004 | 0.003 | 0.003 | 0.008 | 0.010 | 0.004 |

**Table H2** Influences of 1%Pd/HMOR and varied Ni/HMOR

| No. carbon. | Non-catalytic | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 0.248 | 0.164 | 0.282 | 0.050 | 0.097 | 0.101 |
| 5 | 2.099 | 1.584 | 2.328 | 0.605 | 0.880 | 1.036 |
| 6 | 2.668 | 2.441 | 2.844 | 1.251 | 1.253 | 1.729 |
| 7 | 3.301 | 3.516 | 3.390 | 2.222 | 1.729 | 2.622 |
| 8 | 3.974 | 4.721 | 3.943 | 3.430 | 2.312 | 3.634 |
| 9 | 4.650 | 5.905 | 4.470 | 4.683 | 2.991 | 4.632 |
| 10 | 5.280 | 6.885 | 4.938 | 5.761 | 3.742 | 5.479 |
| 11 | 5.811 | 7.515 | 5.313 | 6.506 | 4.519 | 6.074 |
| 12 | 6.193 | 7.726 | 5.568 | 6.862 | 5.262 | 6.376 |
| 13 | 6.390 | 7.545 | 5.688 | 6.864 | 5.897 | 6.402 |
| 14 | 6.386 | 7.061 | 5.669 | 6.594 | 6.358 | 6.205 |
| 15 | 6.193 | 6.390 | 5.521 | 6.149 | 6.596 | 5.850 |
| 16 | 5.841 | 5.638 | 5.267 | 5.612 | 6.596 | 5.402 |
| 17 | 5.378 | 4.884 | 4.933 | 5.044 | 6.375 | 4.913 |
| 18 | 4.850 | 4.178 | 4.548 | 4.487 | 5.978 | 4.420 |
| 19 | 4.302 | 3.546 | 4.140 | 3.967 | 5.461 | 3.948 |
| 20 | 3.766 | 2.998 | 3.730 | 3.494 | 4.883 | 3.510 |
| 21 | 3.265 | 2.530 | 3.334 | 3.073 | 4.293 | 3.114 |
| 22 | 2.812 | 2.136 | 2.962 | 2.703 | 3.726 | 2.760 |
| 23 | 2.411 | 1.806 | 2.621 | 2.380 | 3.203 | 2.447 |
| 24 | 2.063 | 1.532 | 2.313 | 2.100 | 2.736 | 2.172 |
| 25 | 1.763 | 1.304 | 2.038 | 1.857 | 2.327 | 1.932 |
| 26 | 1.506 | 1.114 | 1.795 | 1.647 | 1.975 | 1.721 |
| 27 | 1.289 | 0.955 | 1.580 | 1.464 | 1.674 | 1.537 |
| 28 | 1.104 | 0.821 | 1.392 | 1.305 | 1.419 | 1.376 |
| 29 | 0.947 | 0.709 | 1.227 | 1.167 | 1.204 | 1.234 |
| 30 | 0.814 | 0.614 | 1.082 | 1.045 | 1.022 | 1.109 |
| 31 | 0.700 | 0.534 | 0.955 | 0.938 | 0.868 | 0.998 |
| 32 | 0.604 | 0.465 | 0.843 | 0.843 | 0.739 | 0.900 |
| 33 | 0.521 | 0.405 | 0.745 | 0.758 | 0.629 | 0.812 |
| 34 | 0.450 | 0.354 | 0.658 | 0.683 | 0.537 | 0.732 |
| 35 | 0.389 | 0.310 | 0.581 | 0.614 | 0.458 | 0.661 |
| 36 | 0.336 | 0.271 | 0.512 | 0.553 | 0.391 | 0.596 |
| 37 | 0.291 | 0.237 | 0.451 | 0.497 | 0.333 | 0.536 |
| 38 | 0.251 | 0.207 | 0.397 | 0.446 | 0.284 | 0.482 |
| 39 | 0.216 | 0.181 | 0.348 | 0.399 | 0.242 | 0.431 |
| 40 | 0.186 | 0.157 | 0.305 | 0.355 | 0.206 | 0.385 |
| 41 | 0.160 | 0.136 | 0.265 | 0.314 | 0.174 | 0.341 |
| 42 | 0.136 | 0.117 | 0.229 | 0.277 | 0.147 | 0.300 |
| 43 | 0.115 | 0.100 | 0.196 | 0.241 | 0.123 | 0.262 |
| 44 | 0.096 | 0.085 | 0.166 | 0.207 | 0.102 | 0.225 |
| 45 | 0.079 | 0.070 | 0.138 | 0.174 | 0.083 | 0.189 |
| 46 | 0.063 | 0.056 | 0.111 | 0.142 | 0.066 | 0.154 |
| 47 | 0.048 | 0.043 | 0.085 | 0.110 | 0.050 | 0.120 |
| 48 | 0.033 | 0.030 | 0.060 | 0.077 | 0.035 | 0.084 |
| 49 | 0.019 | 0.017 | 0.034 | 0.044 | 0.020 | 0.048 |
| 50 | 0.004 | 0.003 | 0.007 | 0.009 | 0.004 | 0.010 |

**Table H3** Influences of 1%Ru/HBeta and varied Fe/HBeta

| No. carbon. | Non-catalytic | HBeta | 1%Ru/ HBeta | 5%Fe/ HBeta | 10%Fe/ HBeta | 20%Fe/ HBeta |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 0.248 | 0.080 | 0.070 | 0.081 | 0.053 | 0.171 |
| 5 | 2.099 | 1.470 | 1.106 | 1.016 | 0.756 | 1.694 |
| 6 | 2.668 | 3.952 | 2.673 | 2.199 | 1.876 | 2.681 |
| 7 | 3.301 | 6.881 | 4.607 | 4.014 | 3.665 | 3.879 |
| 8 | 3.974 | 9.068 | 6.318 | 6.199 | 5.801 | 5.139 |
| 9 | 4.650 | 9.995 | 7.426 | 8.201 | 7.698 | 6.263 |
| 10 | 5.280 | 9.829 | 7.860 | 9.489 | 8.883 | 7.073 |
| 11 | 5.811 | 8.989 | 7.749 | 9.843 | 9.216 | 7.474 |
| 12 | 6.193 | 7.854 | 7.282 | 9.388 | 8.847 | 7.468 |
| 13 | 6.390 | 6.674 | 6.627 | 8.420 | 8.040 | 7.134 |
| 14 | 6.386 | 5.581 | 5.905 | 7.236 | 7.039 | 6.579 |
| 15 | 6.193 | 4.628 | 5.192 | 6.045 | 6.013 | 5.910 |
| 16 | 5.841 | 3.826 | 4.529 | 4.963 | 5.059 | 5.210 |
| 17 | 5.378 | 3.164 | 3.935 | 4.036 | 4.221 | 4.533 |
| 18 | 4.850 | 2.623 | 3.414 | 3.269 | 3.509 | 3.912 |
| 19 | 4.302 | 2.184 | 2.964 | 2.647 | 2.915 | 3.359 |
| 20 | 3.766 | 1.828 | 2.578 | 2.149 | 2.427 | 2.879 |
| 21 | 3.265 | 1.538 | 2.250 | 1.751 | 2.027 | 2.468 |
| 22 | 2.812 | 1.302 | 1.970 | 1.435 | 1.700 | 2.118 |
| 23 | 2.411 | 1.109 | 1.731 | 1.183 | 1.433 | 1.822 |
| 24 | 2.063 | 0.951 | 1.528 | 0.980 | 1.215 | 1.572 |
| 25 | 1.763 | 0.819 | 1.354 | 0.818 | 1.035 | 1.361 |
| 26 | 1.506 | 0.710 | 1.205 | 0.686 | 0.886 | 1.183 |
| 27 | 1.289 | 0.619 | 1.076 | 0.579 | 0.762 | 1.032 |
| 28 | 1.104 | 0.541 | 0.964 | 0.491 | 0.659 | 0.903 |
| 29 | 0.947 | 0.476 | 0.867 | 0.419 | 0.572 | 0.793 |
| 30 | 0.814 | 0.420 | 0.782 | 0.359 | 0.498 | 0.698 |
| 31 | 0.700 | 0.372 | 0.707 | 0.308 | 0.436 | 0.616 |
| 32 | 0.604 | 0.330 | 0.640 | 0.266 | 0.382 | 0.545 |
| 33 | 0.521 | 0.293 | 0.580 | 0.230 | 0.335 | 0.483 |
| 34 | 0.450 | 0.261 | 0.526 | 0.199 | 0.295 | 0.429 |
| 35 | 0.389 | 0.233 | 0.478 | 0.173 | 0.260 | 0.380 |
| 36 | 0.336 | 0.207 | 0.433 | 0.150 | 0.229 | 0.338 |
| 37 | 0.291 | 0.185 | 0.393 | 0.130 | 0.202 | 0.299 |
| 38 | 0.251 | 0.164 | 0.355 | 0.113 | 0.178 | 0.265 |
| 39 | 0.216 | 0.146 | 0.320 | 0.098 | 0.156 | 0.234 |
| 40 | 0.186 | 0.129 | 0.287 | 0.085 | 0.137 | 0.206 |
| 41 | 0.160 | 0.114 | 0.256 | 0.073 | 0.119 | 0.181 |
| 42 | 0.136 | 0.100 | 0.227 | 0.063 | 0.103 | 0.158 |
| 43 | 0.115 | 0.086 | 0.199 | 0.054 | 0.089 | 0.136 |
| 44 | 0.096 | 0.074 | 0.172 | 0.045 | 0.075 | 0.116 |
| 45 | 0.079 | 0.062 | 0.145 | 0.037 | 0.063 | 0.097 |
| 46 | 0.063 | 0.050 | 0.119 | 0.030 | 0.051 | 0.078 |
| 47 | 0.048 | 0.039 | 0.092 | 0.023 | 0.039 | 0.060 |
| 48 | 0.033 | 0.027 | 0.065 | 0.016 | 0.027 | 0.042 |
| 49 | 0.019 | 0.016 | 0.037 | 0.009 | 0.016 | 0.024 |
| 50 | 0.004 | 0.003 | 0.008 | 0.002 | 0.003 | 0.005 |

**Table H4** Influences of 1%Ru/HMOR and varied Fe/HMOR

| No. carbon. | Non-catalytic | HMOR | 1%Ru/ HMOR | 5%Fe/ HMOR | 10%Fe/ HMOR | 20%Fe/ HMOR |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 0.248 | 0.164 | 0.155 | 0.465 | 0.160 | 0.085 |
| 5 | 2.099 | 1.584 | 1.695 | 3.817 | 1.723 | 1.095 |
| 6 | 2.668 | 2.441 | 3.019 | 4.571 | 3.027 | 2.353 |
| 7 | 3.301 | 3.516 | 4.682 | 5.269 | 4.699 | 4.120 |
| 8 | 3.974 | 4.721 | 6.374 | 5.846 | 6.457 | 6.029 |
| 9 | 4.650 | 5.905 | 7.724 | 6.249 | 7.918 | 7.597 |
| 10 | 5.280 | 6.885 | 8.479 | 6.448 | 8.781 | 8.501 |
| 11 | 5.811 | 7.515 | 8.593 | 6.440 | 8.952 | 8.690 |
| 12 | 6.193 | 7.726 | 8.186 | 6.248 | 8.535 | 8.309 |
| 13 | 6.390 | 7.545 | 7.448 | 5.912 | 7.735 | 7.575 |
| 14 | 6.386 | 7.061 | 6.557 | 5.478 | 6.758 | 6.682 |
| 15 | 6.193 | 6.390 | 5.645 | 4.991 | 5.757 | 5.768 |
| 16 | 5.841 | 5.638 | 4.789 | 4.488 | 4.826 | 4.910 |
| 17 | 5.378 | 4.884 | 4.029 | 3.997 | 4.006 | 4.148 |
| 18 | 4.850 | 4.178 | 3.376 | 3.536 | 3.310 | 3.491 |
| 19 | 4.302 | 3.546 | 2.826 | 3.114 | 2.732 | 2.937 |
| 20 | 3.766 | 2.998 | 2.368 | 2.736 | 2.258 | 2.474 |
| 21 | 3.265 | 2.530 | 1.990 | 2.402 | 1.871 | 2.090 |
| 22 | 2.812 | 2.136 | 1.679 | 2.110 | 1.558 | 1.773 |
| 23 | 2.411 | 1.806 | 1.422 | 1.855 | 1.303 | 1.511 |
| 24 | 2.063 | 1.532 | 1.211 | 1.634 | 1.095 | 1.293 |
| 25 | 1.763 | 1.304 | 1.036 | 1.443 | 0.926 | 1.112 |
| 26 | 1.506 | 1.114 | 0.890 | 1.278 | 0.787 | 0.961 |
| 27 | 1.289 | 0.955 | 0.769 | 1.134 | 0.672 | 0.835 |
| 28 | 1.104 | 0.821 | 0.667 | 1.009 | 0.576 | 0.728 |
| 29 | 0.947 | 0.709 | 0.581 | 0.900 | 0.497 | 0.637 |
| 30 | 0.814 | 0.614 | 0.508 | 0.804 | 0.430 | 0.559 |
| 31 | 0.700 | 0.534 | 0.445 | 0.720 | 0.373 | 0.493 |
| 32 | 0.604 | 0.465 | 0.391 | 0.646 | 0.325 | 0.435 |
| 33 | 0.521 | 0.405 | 0.345 | 0.580 | 0.283 | 0.385 |
| 34 | 0.450 | 0.354 | 0.304 | 0.521 | 0.248 | 0.341 |
| 35 | 0.389 | 0.310 | 0.268 | 0.468 | 0.217 | 0.303 |
| 36 | 0.336 | 0.271 | 0.237 | 0.420 | 0.190 | 0.269 |
| 37 | 0.291 | 0.237 | 0.209 | 0.376 | 0.166 | 0.238 |
| 38 | 0.251 | 0.207 | 0.185 | 0.337 | 0.146 | 0.211 |
| 39 | 0.216 | 0.181 | 0.163 | 0.300 | 0.127 | 0.186 |
| 40 | 0.186 | 0.157 | 0.143 | 0.267 | 0.111 | 0.164 |
| 41 | 0.160 | 0.136 | 0.125 | 0.236 | 0.096 | 0.144 |
| 42 | 0.136 | 0.117 | 0.108 | 0.207 | 0.083 | 0.125 |
| 43 | 0.115 | 0.100 | 0.093 | 0.180 | 0.071 | 0.108 |
| 44 | 0.096 | 0.085 | 0.079 | 0.154 | 0.060 | 0.092 |
| 45 | 0.079 | 0.070 | 0.066 | 0.129 | 0.050 | 0.077 |
| 46 | 0.063 | 0.056 | 0.053 | 0.105 | 0.040 | 0.062 |
| 47 | 0.048 | 0.043 | 0.041 | 0.081 | 0.031 | 0.048 |
| 48 | 0.033 | 0.030 | 0.029 | 0.057 | 0.021 | 0.034 |
| 49 | 0.019 | 0.017 | 0.016 | 0.033 | 0.012 | 0.019 |
| 50 | 0.004 | 0.003 | 0.003 | 0.007 | 0.002 | 0.004 |

## Appendix I Carbon Number Distribution of Mono-aromatics

**Table I1** Influences of 1%Pd/HBeta and varied Ni/HBeta

| No. carbon. | Non-catalytic | HBeta | 1%Pd/ HBeta | 5%Ni/ HBeta | 10%Ni/ HBeta | 20%Ni/ HBeta |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.220 | 0.000 |
| 3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.289 | 0.000 |
| 4 | 0.015 | 0.051 | 0.115 | 0.000 | 0.370 | 0.000 |
| 5 | 0.138 | 0.460 | 0.961 | 0.000 | 0.464 | 0.000 |
| 6 | 0.208 | 0.647 | 1.209 | 0.000 | 0.572 | 0.000 |
| 7 | 0.305 | 0.885 | 1.493 | 0.000 | 0.692 | 0.000 |
| 8 | 0.434 | 1.183 | 1.811 | 0.000 | 0.823 | 0.000 |
| 9 | 0.602 | 1.545 | 2.160 | 0.000 | 0.965 | 0.001 |
| 10 | 0.813 | 1.977 | 2.538 | 0.000 | 1.115 | 0.023 |
| 11 | 1.073 | 2.479 | 2.939 | 0.002 | 1.273 | 0.267 |
| 12 | 1.385 | 3.055 | 3.360 | 0.042 | 1.435 | 1.253 |
| 13 | 1.752 | 3.701 | 3.793 | 0.302 | 1.601 | 3.261 |
| 14 | 2.172 | 4.412 | 4.233 | 1.103 | 1.770 | 5.745 |
| 15 | 2.643 | 5.177 | 4.668 | 2.557 | 1.940 | 7.822 |
| 16 | 3.155 | 5.973 | 5.085 | 4.353 | 2.110 | 8.984 |
| 17 | 3.696 | 6.758 | 5.467 | 6.000 | 2.280 | 9.223 |
| 18 | 4.244 | 7.462 | 5.790 | 7.153 | 2.450 | 8.793 |
| 19 | 4.775 | 7.977 | 6.021 | 7.714 | 2.621 | 7.984 |
| 20 | 5.254 | 8.171 | 6.126 | 7.762 | 2.793 | 7.025 |
| 21 | 5.646 | 7.924 | 6.072 | 7.445 | 2.966 | 6.059 |
| 22 | 5.916 | 7.203 | 5.836 | 6.907 | 3.142 | 5.163 |
| 23 | 6.037 | 6.106 | 5.420 | 6.263 | 3.322 | 4.370 |
| 24 | 5.994 | 4.843 | 4.854 | 5.591 | 3.506 | 3.686 |
| 25 | 5.790 | 3.630 | 4.193 | 4.940 | 3.696 | 3.107 |
| 26 | 5.445 | 2.607 | 3.502 | 4.336 | 3.892 | 2.621 |
| 27 | 4.993 | 1.820 | 2.841 | 3.789 | 4.095 | 2.215 |
| 28 | 4.474 | 1.249 | 2.250 | 3.303 | 4.304 | 1.877 |
| 29 | 3.927 | 0.850 | 1.750 | 2.876 | 4.516 | 1.594 |
| 30 | 3.386 | 0.577 | 1.343 | 2.502 | 4.727 | 1.357 |
| 31 | 2.877 | 0.393 | 1.022 | 2.177 | 4.922 | 1.158 |
| 32 | 2.415 | 0.268 | 0.773 | 1.894 | 5.076 | 0.991 |
| 33 | 2.007 | 0.184 | 0.583 | 1.648 | 5.139 | 0.849 |
| 34 | 1.655 | 0.127 | 0.440 | 1.434 | 5.023 | 0.729 |
| 35 | 1.357 | 0.089 | 0.332 | 1.247 | 4.619 | 0.627 |
| 36 | 1.108 | 0.062 | 0.251 | 1.085 | 3.871 | 0.539 |
| 37 | 0.902 | 0.044 | 0.190 | 0.942 | 2.882 | 0.464 |
| 38 | 0.732 | 0.031 | 0.144 | 0.817 | 1.904 | 0.399 |
| 39 | 0.593 | 0.022 | 0.110 | 0.708 | 1.145 | 0.343 |
| 40 | 0.479 | 0.016 | 0.084 | 0.611 | 0.650 | 0.294 |
| 41 | 0.387 | 0.012 | 0.064 | 0.525 | 0.361 | 0.251 |
| 42 | 0.311 | 0.008 | 0.049 | 0.449 | 0.200 | 0.213 |
| 43 | 0.249 | 0.006 | 0.038 | 0.381 | 0.112 | 0.180 |
| 44 | 0.198 | 0.005 | 0.029 | 0.319 | 0.064 | 0.150 |
| 45 | 0.155 | 0.003 | 0.022 | 0.263 | 0.037 | 0.123 |
| 46 | 0.119 | 0.002 | 0.016 | 0.210 | 0.022 | 0.098 |
| 47 | 0.088 | 0.002 | 0.012 | 0.160 | 0.013 | 0.075 |
| 48 | 0.060 | 0.001 | 0.008 | 0.112 | 0.008 | 0.052 |
| 49 | 0.033 | 0.001 | 0.004 | 0.063 | 0.004 | 0.029 |
| 50 | 0.007 | 0.000 | 0.001 | 0.013 | 0.001 | 0.006 |

**Table I2** Influences of 1%Pd/HMOR and varied Ni/HMOR

| No. carbon. | Non-catalytic | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 0.015 | 0.000 | 0.002 | 0.032 | 0.007 | 0.022 |
| 5 | 0.138 | 0.347 | 0.019 | 0.286 | 0.072 | 0.203 |
| 6 | 0.208 | 30.472 | 0.037 | 0.391 | 0.126 | 0.302 |
| 7 | 0.305 | 45.567 | 0.070 | 0.522 | 0.211 | 0.435 |
| 8 | 0.434 | 17.066 | 0.127 | 0.681 | 0.337 | 0.609 |
| 9 | 0.602 | 4.705 | 0.221 | 0.870 | 0.517 | 0.832 |
| 10 | 0.813 | 1.290 | 0.367 | 1.089 | 0.763 | 1.110 |
| 11 | 1.073 | 0.375 | 0.585 | 1.340 | 1.082 | 1.449 |
| 12 | 1.385 | 0.117 | 0.898 | 1.621 | 1.476 | 1.853 |
| 13 | 1.752 | 0.039 | 1.326 | 1.932 | 1.938 | 2.325 |
| 14 | 2.172 | 0.014 | 1.882 | 2.270 | 2.451 | 2.868 |
| 15 | 2.643 | 0.005 | 2.568 | 2.634 | 2.990 | 3.480 |
| 16 | 3.155 | 0.002 | 3.361 | 3.021 | 3.523 | 4.158 |
| 17 | 3.696 | 0.001 | 4.218 | 3.427 | 4.014 | 4.889 |
| 18 | 4.244 | 0.000 | 5.067 | 3.846 | 4.434 | 5.652 |
| 19 | 4.775 | 0.000 | 5.824 | 4.272 | 4.758 | 6.406 |
| 20 | 5.254 | 0.000 | 6.408 | 4.692 | 4.974 | 7.086 |
| 21 | 5.646 | 0.000 | 6.758 | 5.091 | 5.078 | 7.598 |
| 22 | 5.916 | 0.000 | 6.848 | 5.445 | 5.078 | 7.831 |
| 23 | 6.037 | 0.000 | 6.692 | 5.726 | 4.987 | 7.688 |
| 24 | 5.994 | 0.000 | 6.332 | 5.901 | 4.822 | 7.135 |
| 25 | 5.790 | 0.000 | 5.828 | 5.934 | 4.600 | 6.238 |
| 26 | 5.445 | 0.000 | 5.241 | 5.801 | 4.340 | 5.146 |
| 27 | 4.993 | 0.000 | 4.625 | 5.495 | 4.055 | 4.034 |
| 28 | 4.474 | 0.000 | 4.019 | 5.031 | 3.758 | 3.036 |
| 29 | 3.927 | 0.000 | 3.452 | 4.450 | 3.459 | 2.217 |
| 30 | 3.386 | 0.000 | 2.937 | 3.810 | 3.165 | 1.587 |
| 31 | 2.877 | 0.000 | 2.482 | 3.165 | 2.881 | 1.123 |
| 32 | 2.415 | 0.000 | 2.086 | 2.564 | 2.611 | 0.789 |
| 33 | 2.007 | 0.000 | 1.746 | 2.034 | 2.356 | 0.554 |
| 34 | 1.655 | 0.000 | 1.458 | 1.589 | 2.118 | 0.389 |
| 35 | 1.357 | 0.000 | 1.214 | 1.226 | 1.897 | 0.274 |
| 36 | 1.108 | 0.000 | 1.010 | 0.939 | 1.693 | 0.194 |
| 37 | 0.902 | 0.000 | 0.838 | 0.716 | 1.505 | 0.138 |
| 38 | 0.732 | 0.000 | 0.695 | 0.544 | 1.333 | 0.099 |
| 39 | 0.593 | 0.000 | 0.576 | 0.413 | 1.175 | 0.071 |
| 40 | 0.479 | 0.000 | 0.476 | 0.313 | 1.031 | 0.051 |
| 41 | 0.387 | 0.000 | 0.393 | 0.238 | 0.899 | 0.037 |
| 42 | 0.311 | 0.000 | 0.323 | 0.181 | 0.779 | 0.027 |
| 43 | 0.249 | 0.000 | 0.264 | 0.138 | 0.667 | 0.020 |
| 44 | 0.198 | 0.000 | 0.213 | 0.104 | 0.564 | 0.015 |
| 45 | 0.155 | 0.000 | 0.170 | 0.078 | 0.468 | 0.011 |
| 46 | 0.119 | 0.000 | 0.133 | 0.058 | 0.377 | 0.008 |
| 47 | 0.088 | 0.000 | 0.099 | 0.042 | 0.289 | 0.005 |
| 48 | 0.060 | 0.000 | 0.068 | 0.028 | 0.202 | 0.004 |
| 49 | 0.033 | 0.000 | 0.038 | 0.015 | 0.115 | 0.002 |
| 50 | 0.007 | 0.000 | 0.008 | 0.003 | 0.023 | 0.000 |

**Table 13** Influences of 1%Ru/HBeta and varied Fe/HBeta

| No. carbon. | Non-catalytic | HBeta | 1%Ru/ HBeta | 5%Fe/ HBeta | 10%Fe/ HBeta | 20%Fe/ HBeta |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 0.015 | 0.051 | 0.046 | 0.007 | 0.472 | 0.384 |
| 5 | 0.138 | 0.460 | 0.464 | 0.066 | 3.676 | 2.826 |
| 6 | 0.208 | 0.647 | 0.793 | 0.091 | 4.022 | 2.868 |
| 7 | 0.305 | 0.885 | 1.303 | 0.121 | 4.254 | 2.895 |
| 8 | 0.434 | 1.183 | 2.058 | 0.158 | 4.379 | 2.909 |
| 9 | 0.602 | 1.545 | 3.123 | 0.202 | 4.412 | 2.910 |
| 10 | 0.813 | 1.977 | 4.542 | 0.254 | 4.370 | 2.899 |
| 11 | 1.073 | 2.479 | 6.289 | 0.313 | 4.272 | 2.878 |
| 12 | 1.385 | 3.055 | 8.206 | 0.379 | 4.133 | 2.850 |
| 13 | 1.752 | 3.701 | 9.948 | 0.452 | 3.967 | 2.814 |
| 14 | 2.172 | 4.412 | 11.037 | 0.532 | 3.785 | 2.773 |
| 15 | 2.643 | 5.177 | 11.087 | 0.618 | 3.596 | 2.729 |
| 16 | 3.155 | 5.973 | 10.071 | 0.711 | 3.406 | 2.682 |
| 17 | 3.696 | 6.758 | 8.356 | 0.810 | 3.220 | 2.634 |
| 18 | 4.244 | 7.462 | 6.454 | 0.914 | 3.042 | 2.586 |
| 19 | 4.775 | 7.977 | 4.739 | 1.025 | 2.873 | 2.540 |
| 20 | 5.254 | 8.171 | 3.375 | 1.142 | 2.714 | 2.495 |
| 21 | 5.646 | 7.924 | 2.365 | 1.265 | 2.566 | 2.454 |
| 22 | 5.916 | 7.203 | 1.649 | 1.395 | 2.430 | 2.415 |
| 23 | 6.037 | 6.106 | 1.152 | 1.533 | 2.305 | 2.380 |
| 24 | 5.994 | 4.843 | 0.809 | 1.679 | 2.190 | 2.349 |
| 25 | 5.790 | 3.630 | 0.573 | 1.834 | 2.084 | 2.321 |
| 26 | 5.445 | 2.607 | 0.409 | 1.998 | 1.988 | 2.297 |
| 27 | 4.993 | 1.820 | 0.295 | 2.174 | 1.899 | 2.276 |
| 28 | 4.474 | 1.249 | 0.215 | 2.360 | 1.817 | 2.259 |
| 29 | 3.927 | 0.850 | 0.158 | 2.557 | 1.741 | 2.243 |
| 30 | 3.386 | 0.577 | 0.117 | 2.766 | 1.671 | 2.229 |
| 31 | 2.877 | 0.393 | 0.087 | 2.985 | 1.604 | 2.216 |
| 32 | 2.415 | 0.268 | 0.066 | 3.213 | 1.540 | 2.202 |
| 33 | 2.007 | 0.184 | 0.050 | 3.449 | 1.478 | 2.187 |
| 34 | 1.655 | 0.127 | 0.038 | 3.689 | 1.417 | 2.169 |
| 35 | 1.357 | 0.089 | 0.029 | 3.930 | 1.357 | 2.147 |
| 36 | 1.108 | 0.062 | 0.022 | 4.164 | 1.297 | 2.119 |
| 37 | 0.902 | 0.044 | 0.017 | 4.386 | 1.236 | 2.083 |
| 38 | 0.732 | 0.031 | 0.013 | 4.585 | 1.173 | 2.038 |
| 39 | 0.593 | 0.022 | 0.010 | 4.750 | 1.107 | 1.983 |
| 40 | 0.479 | 0.016 | 0.008 | 4.866 | 1.039 | 1.914 |
| 41 | 0.387 | 0.012 | 0.006 | 4.916 | 0.966 | 1.830 |
| 42 | 0.311 | 0.008 | 0.005 | 4.880 | 0.890 | 1.729 |
| 43 | 0.249 | 0.006 | 0.004 | 4.735 | 0.808 | 1.608 |
| 44 | 0.198 | 0.005 | 0.003 | 4.459 | 0.721 | 1.467 |
| 45 | 0.155 | 0.003 | 0.002 | 4.037 | 0.627 | 1.302 |
| 46 | 0.119 | 0.002 | 0.002 | 3.469 | 0.527 | 1.112 |
| 47 | 0.088 | 0.002 | 0.001 | 2.776 | 0.418 | 0.895 |
| 48 | 0.060 | 0.001 | 0.001 | 1.990 | 0.301 | 0.651 |
| 49 | 0.033 | 0.001 | 0.000 | 1.138 | 0.174 | 0.378 |
| 50 | 0.007 | 0.000 | 0.000 | 0.228 | 0.035 | 0.077 |

**Table I4** Influences of 1%Ru/HMOR and varied Fe/HMOR

| No. carbon. | Non-catalytic | HMOR | 1%Pd/ HMOR | 5%Ni/ HMOR | 10%Ni/ HMOR | 20%Ni/ HMOR |
|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 0.015 | 0.000 | 0.001 | 0.012 | 0.699 | 0.038 |
| 5 | 0.138 | 0.347 | 0.017 | 0.103 | 4.963 | 0.410 |
| 6 | 0.208 | 30.472 | 0.055 | 0.137 | 4.746 | 0.751 |
| 7 | 0.305 | 45.567 | 0.159 | 0.178 | 4.531 | 1.308 |
| 8 | 0.434 | 17.066 | 0.427 | 0.226 | 4.320 | 2.162 |
| 9 | 0.602 | 4.705 | 1.048 | 0.282 | 4.114 | 3.375 |
| 10 | 0.813 | 1.290 | 2.327 | 0.345 | 3.915 | 4.945 |
| 11 | 1.073 | 0.375 | 4.582 | 0.415 | 3.723 | 6.738 |
| 12 | 1.385 | 0.117 | 7.808 | 0.492 | 3.539 | 8.458 |
| 13 | 1.752 | 0.039 | 11.245 | 0.576 | 3.365 | 9.715 |
| 14 | 2.172 | 0.014 | 13.528 | 0.665 | 3.199 | 10.189 |
| 15 | 2.643 | 0.005 | 13.714 | 0.760 | 3.044 | 9.808 |
| 16 | 3.155 | 0.002 | 12.046 | 0.859 | 2.898 | 8.763 |
| 17 | 3.696 | 0.001 | 9.517 | 0.964 | 2.763 | 7.376 |
| 18 | 4.244 | 0.000 | 7.014 | 1.072 | 2.637 | 5.942 |
| 19 | 4.775 | 0.000 | 4.965 | 1.185 | 2.521 | 4.648 |
| 20 | 5.254 | 0.000 | 3.446 | 1.303 | 2.415 | 3.570 |
| 21 | 5.646 | 0.000 | 2.376 | 1.426 | 2.318 | 2.717 |
| 22 | 5.916 | 0.000 | 1.642 | 1.554 | 2.229 | 2.061 |
| 23 | 6.037 | 0.000 | 1.141 | 1.688 | 2.149 | 1.565 |
| 24 | 5.994 | 0.000 | 0.801 | 1.828 | 2.076 | 1.193 |
| 25 | 5.790 | 0.000 | 0.568 | 1.976 | 2.010 | 0.914 |
| 26 | 5.445 | 0.000 | 0.407 | 2.132 | 1.951 | 0.705 |
| 27 | 4.993 | 0.000 | 0.295 | 2.296 | 1.897 | 0.547 |
| 28 | 4.474 | 0.000 | 0.215 | 2.469 | 1.848 | 0.427 |
| 29 | 3.927 | 0.000 | 0.159 | 2.651 | 1.803 | 0.336 |
| 30 | 3.386 | 0.000 | 0.118 | 2.842 | 1.761 | 0.266 |
| 31 | 2.877 | 0.000 | 0.089 | 3.041 | 1.721 | 0.211 |
| 32 | 2.415 | 0.000 | 0.067 | 3.246 | 1.683 | 0.169 |
| 33 | 2.007 | 0.000 | 0.051 | 3.456 | 1.645 | 0.136 |
| 34 | 1.655 | 0.000 | 0.039 | 3.667 | 1.606 | 0.109 |
| 35 | 1.357 | 0.000 | 0.030 | 3.876 | 1.566 | 0.089 |
| 36 | 1.108 | 0.000 | 0.023 | 4.077 | 1.524 | 0.072 |
| 37 | 0.902 | 0.000 | 0.018 | 4.262 | 1.477 | 0.059 |
| 38 | 0.732 | 0.000 | 0.014 | 4.425 | 1.426 | 0.048 |
| 39 | 0.593 | 0.000 | 0.011 | 4.553 | 1.369 | 0.039 |
| 40 | 0.479 | 0.000 | 0.009 | 4.634 | 1.305 | 0.032 |
| 41 | 0.387 | 0.000 | 0.007 | 4.652 | 1.233 | 0.026 |
| 42 | 0.311 | 0.000 | 0.005 | 4.589 | 1.152 | 0.021 |
| 43 | 0.249 | 0.000 | 0.004 | 4.425 | 1.061 | 0.017 |
| 44 | 0.198 | 0.000 | 0.003 | 4.143 | 0.959 | 0.014 |
| 45 | 0.155 | 0.000 | 0.003 | 3.729 | 0.844 | 0.011 |
| 46 | 0.119 | 0.000 | 0.002 | 3.189 | 0.716 | 0.009 |
| 47 | 0.088 | 0.000 | 0.001 | 2.541 | 0.573 | 0.006 |
| 48 | 0.060 | 0.000 | 0.001 | 1.816 | 0.415 | 0.004 |
| 49 | 0.033 | 0.000 | 0.001 | 1.037 | 0.240 | 0.002 |
| 50 | 0.007 | 0.000 | 0.000 | 0.208 | 0.049 | 0.000 |

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1. Saeaeh, L. and Jitkarnka, S. (2012, April 11-13) Investigation of Nickel as a Metal Substitute of Palladium Supported on HBeta Zeolite for Waste Tire Pyrolysis, Poster presentation at ICCBEE 2012 : International Conference on Chemical, Biological and Environmental Engineering, Venice, Italy.
2. Saeaeh, L. and Jitkarnka, S. (2012, April 24) Nickel as a Metal Substitute for Palladium Supported on HMOR Zeolite for Waste Tire Pyrolysis. Paper presented at the 3rd Research Symposium on Petrochemical and Materials Technology, and the 18th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.