**Appendices (A-C)**

Title: **A Unified Benchmark for Security and Reliability Assessment of the Integrated Chemical Plant, Natural Gas and Power Transmission Networks**

Authors: Zahra Kheirkhah Ravandi, R. Bozorgmehry Boozarjomehry, F. Babaei, S. M. R. Pishvaie

**Appendix A. Data for the gas pipeline and geographical coordinates of the syngas plant, natural gas, and power transmission networks.**

The pipeline data as well as the geographical coordinates of the Syngas plant, natural gas, and power transmission networks are given in Table A.1 to Table A.5.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Starting Node** | **Ending Node** | **Length**  **[ Km]** | **Diameter**  **[ m]** |  | **Node Number** | **Type** | **Latitude** | **Longitude** |
| 1 | 2 | 100 | 0.9144 |  | 1 | supply | 32.73863 | -114.63904 |
| 2 | 3 | 30 | 0.6350 |  | 2 | Node | 32.99842 | -115.50248 |
| 3 | 4 | 5 | 0.6350 |  | 3 | Node | 32.91879 | -115.76985 |
| 4 | 5 | 15 | 0.6350 |  | 4 | Node | 32.78977 | -115.85446 |
| 5 | 6 | 10 | 0.6350 |  | 5 | Node | 32.73448 | -116.0316 |
| 6 | 7 | 5 | 0.6350 |  | 6 | SynGas  Demand | 32.63406 | -116.20342 |
| 7 | 8 | 10 | 0.6350 |  | 7 | Node | 32.7819 | -116.13369 |
| 8 | 9 | 5 | 0.9144 |  | 8 | Power  Demand | 32.81886 | -116.32434 |
| 9 | 10 | 60 | 0.9144 |  | 9 | Node | 33.06292 | -115.39132 |
| 10 | 11 | 5 | 0.6350 |  | 10 | Node | 33.54045 | -114.9868 |
| 11 | 12 | 8 | 0.6350 |  | 11 | Node | 33.52901 | -115.16741 |
| 11 | 13 | 6 | 0.6350 |  | 12 | Demand | 33.68336 | -115.17709 |
| 10 | 14 | 80 | 0.9144 |  | 13 | Power  Demand | 33.50618 | -115.3295 |
| 14 | 15 | 10 | 0.9144 |  | 14 | Node | 33.65556 | -114.2273 |
| 15 | 16 | 20 | 0.9144 |  | 15 | Node | 33.67138 | -113.99405 |
| 16 | 17 | 3 | 0.6350 |  | 16 | Node | 33.63961 | -113.74963 |
| 17 | 18 | 6 | 0.6350 |  | 17 | Node | 33.59129 | -113.55726 |
| 16 | 19 | 5 | 0.6350 |  | 18 | Demand | 33.57985 | -113.36486 |
| 15 | 20 | 40 | 0.9144 |  | 19 | Power  Demand | 33.73234 | -113.67656 |
| 20 | 21 | 5 | 0.9144 |  | 20 | Node | 33.86509 | -113.97678 |
| 21 | 22 | 20 | 0.9144 |  | 21 | Node | 33.97907 | -114.07031 |
| 22 | 23 | 5 | 0.9144 |  | 22 | Node | 34.02234 | -114.22682 |
| 23 | 24 | 16 | 0.9144 |  | 23 | Node | 34.10874 | -114.13616 |
| 22 | 25 | 8 | 0.6350 |  | 24 | Power  Demand | 34.21138 | -114.13185 |
| **Table A1.**  The natural gas pipeline data [1] . | | | |  | 25 | Demand | 34.14052 | -114.28999 |

**Table A3.**

The natural gas topology data.

|  |  |
| --- | --- |
| **Latitude** | **Longitude** |
| 32.63406 | -116.20342 |
| **Table A.4**  SynGas plant topology data. | |

|  |  |  |
| --- | --- | --- |
| **Bus ID** | **Latitude** | **Longitude** |
| 1 | 33.396 | -113.836 |
| 2 | 33.358 | -113.826 |
| 3 | 33.537 | -114.670 |
| 4 | 33.812 | -113.825 |
| 5 | 33.659 | -113.999 |
| 6 | 33.738 | -114.182 |
| 7 | 33.732 | -113.677 |
| 8 | 34.459 | -113.762 |
| 9 | 33.920 | -114.308 |
| 10 | 33.913 | -114.293 |
| 11 | 33.904 | -114.301 |
| 12 | 33.911 | -114.3134 |
| 13 | 34.211 | -114.132 |
| 14 | 33.777 | -114.820 |
| 15 | 33.506 | -115.329 |
| 16 | 33.661 | -115.321 |
| 17 | 33.575 | -115.641 |
| 18 | 33.544 | -115.801 |
| 19 | 33.869 | -115.369 |
| 20 | 34.244 | -115.262 |
| 21 | 33.527 | -116.071 |
| 22 | 32.818 | -116.324 |
| 23 | 34.382 | -115.069 |
| 24 | 33.543 | -114.656 |
| **Table A.2**  Power network topology data. | | |

|  |  |  |
| --- | --- | --- |
| **Node number** |  |  |
| 1 | 1.48473 | 0.031129 |
| 2 | 1.448602 | 0.031129 |
| 3 | 1.41155 | 0.031129 |
| 4 | 1.373498 | 0.031129 |
| 5 | 1.334362 | 0.031129 |
| 6 | 1.294042 | 0.031129 |
| 7 | 1.252426 | 0.031129 |
| 8 | 1.209378 | 0.031129 |
| 9 | 1.16474 | 0.031129 |
| 10 | 1.118321 | 0.031129 |
| 11 | 1.116204 | 0.005481 |
| 12 | 1.114084 | 0.005481 |
| 13 | 1.111959 | 0.005481 |
| 14 | 1.422476 | 0.005481 |
| 15 | 1.421228 | 0.005481 |
| 16 | 1.41998 | 0.005481 |
| 17 | 1.419563 | 0.00274 |
| 18 | 1.419772 | 0.00274 |
| 19 | 1.419355 | 0.00274 |
| 20 | 1.463949 | 0.025649 |
| 21 | 1.439167 | 0.025649 |
| 22 | 1.413951 | 0.025649 |
| 23 | 1.388276 | 0.025649 |
| 24 | 1.362118 | 0.025649 |
| 25 | 1.335448 | 0.025649 |
| 26 | 1.308234 | 0.025649 |
| 27 | 1.306561 | 0.007454 |
| 28 | 1.306546 | 0.000548 |
| 29 | 1.304836 | 0.006905 |
| 30 | 1.294322 | 0.018195 |
| 31 | 1.280259 | 0.018195 |
| 32 | 1.26604 | 0.018195 |
| 33 | 1.251659 | 0.018195 |
| 34 | 1.237111 | 0.018195 |
| 35 | 1.22239 | 0.018195 |
| 36 | 1.207489 | 0.018195 |
| 37 | 1.192403 | 0.018195 |
| 38 | 1.478308 | 0.018195 |
| 39 | 1.472212 | 0.012824 |
| 40 | 1.46609 | 0.012824 |
| 41 | 1.466086 | 0.000548 |
| 42 | 1.466076 | 0.000548 |
| 43 | 1.462038 | 0.012276 |
| 44 | 1.47724 | 0.005371 |
| 45 | 1.476172 | 0.005371 |
| 46 | 1.475103 | 0.005371 |
| 47 | 1.474034 | 0.005371 |
| 48 | 1.53248 | 0.005371 |
| 49 | 1.531451 | 0.005371 |
| 50 | 1.53042 | 0.005371 |
| 51 | 1.530005 | 0.004823 |
| 52 | 1.52934 | 0.004823 |
| 53 | 1.528674 | 0.004823 |
| 54 | 1.530408 | 0.000548 |
| **Table A.5**  The initial condition data of gas network. | | |

**Appendix B. Data for the power transmission network in the nominal condition**

Table B.6 to Table B.9 provide the base case data for the power transmission network in its nominal operating condition of the integrated system.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  | **area** |  |  | **Base** | **zone** |  |  |
| 1 | 2 | 93.2256 | 18.9904 | 0 | 0 | 1 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 2 | 2 | 83.7304 | 17.264 | 0 | 0 | 1 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 3 | 1 | 155.376 | 31.9384 | 0 | 0 | 1 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 4 | 1 | 63.8768 | 12.948 | 0 | 0 | 1 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 5 | 1 | 61.2872 | 12.0848 | 0 | 0 | 1 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 6 | 1 | 68 | 14 | 0 | -100 | 2 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 7 | 2 | 107.9 | 21.58 | 0 | 0 | 2 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 8 | 1 | 147.6072 | 30.212 | 0 | 0 | 2 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 9 | 1 | 87.5 | 18 | 0 | 0 | 1 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 10 | 1 | 97.5 | 20 | 0 | 0 | 2 | 1 | 0 | 138 | 1 | 1.05 | 0.95 |
| 11 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 12 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 13 | 3 | 228.748 | 46.6128 | 0 | 0 | 3 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 14 | 2 | 97 | 19.5 | 0 | 0 | 3 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 15 | 2 | 158.5 | 32 | 0 | 0 | 4 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 16 | 2 | 86.32 | 17.264 | 0 | 0 | 4 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 17 | 1 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 18 | 2 | 166.5 | 34 | 0 | 0 | 4 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 19 | 1 | 90.5 | 18.5 | 0 | 0 | 3 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 20 | 1 | 64 | 13 | 0 | 0 | 3 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 21 | 2 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 22 | 2 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 23 | 2 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |
| 24 | 1 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 230 | 1 | 1.05 | 0.95 |

**Table B.6**

Bus data of the power transmission network in the base case [2].

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bus number** | **Type of load** | **Bus load** | **Load** | **If peak load**  **25 %higher** |
|  | **A, B, Const** | **% of load system** |  |  |
| 1 | B | 4.85 | 86.4 | 108 |
| 2 | A | 4.35 | 77.6 | 97 |
| 3 | A | 8.08 | 144 | 180 |
| 4 | A | 3.32 | 59.2 | 74 |
| 5 | A | 3.19 | 56.8 | 71 |
| 6 | Const | 3.81 | 68 | 85 |
| 7 | B | 5.61 | 100 | 125 |
| 8 | B | 7.68 | 136.8 | 171 |
| 9 | Const | 4.91 | 87.5 | 109.375 |
| 10 | Const | 5.47 | 97.5 | 121.875 |
| 13 | A | 11.89 | 212 | 265 |
| 14 | Const | 5.44 | 97 | 121.25 |
| 15 | Const | 8.89 | 158.5 | 198.125 |
| 16 | B | 4.49 | 80 | 100 |
| 18 | Const | 9.34 | 166.5 | 208.125 |
| 19 | Const | 5.08 | 90.5 | 113.125 |
| 20 | Const | 3.59 | 64 | 80 |
|  |  | Total 100 |  |  |

**Table B.7**

Bus load data of the power transmission network in the base case [2].

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus** |  |  |  |  |  | **mBase** | **Status** |  |  |
| 1 | 10 | 0 | 8 | 0 | 1.035 | 100 | 1 | 16 | 8 |
| 1 | 10 | 0 | 8 | 0 | 1.035 | 100 | 1 | 16 | 8 |
| 1 | 60.8 | 0 | 24 | -12.5 | 1.035 | 100 | 1 | 60.8 | 7.6 |
| 1 | 60.8 | 0 | 24 | -12.5 | 1.035 | 100 | 1 | 60.8 | 7.6 |
| 2 | 12 | 0 | 8 | 0 | 1.035 | 100 | 1 | 16 | 8 |
| 2 | 12 | 0 | 8 | 0 | 1.035 | 100 | 1 | 16 | 8 |
| 2 | 60.8 | 0 | 24 | -12.5 | 1.035 | 100 | 1 | 60.8 | 7.6 |
| 2 | 60.8 | 0 | 24 | -12.5 | 1.035 | 100 | 1 | 60.8 | 7.6 |
| 7 | 60 | 0 | 48 | 0 | 1.025 | 100 | 1 | 80 | 8.333333 |
| 7 | 60 | 0 | 48 | 0 | 1.025 | 100 | 1 | 80 | 8.333333 |
| 7 | 60 | 0 | 48 | 0 | 1.025 | 100 | 1 | 80 | 8.333333 |
| 13 | 57.6 | 0 | 64 | 0 | 1.02 | 100 | 1 | 157.6 | 23 |
| 13 | 57.6 | 0 | 64 | 0 | 1.02 | 100 | 1 | 157.6 | 23 |
| 13 | 57.6 | 0 | 64 | 0 | 1.02 | 100 | 1 | 157.6 | 23 |
| 14 | 0 | 35.3 | 160 | -50 | 0.98 | 100 | 1 | 0 | 0 |
| 15 | 9.6 | 0 | 4.8 | 0 | 1.014 | 100 | 1 | 9.6 | 0.48 |
| 15 | 9.6 | 0 | 4.8 | 0 | 1.014 | 100 | 1 | 9.6 | 0.48 |
| 15 | 9.6 | 0 | 4.8 | 0 | 1.014 | 100 | 1 | 9.6 | 0.48 |
| 15 | 9.6 | 0 | 4.8 | 0 | 1.014 | 100 | 1 | 9.6 | 0.48 |
| 15 | 9.6 | 0 | 4.8 | 0 | 1.014 | 100 | 1 | 9.6 | 0.48 |
| 15 | 124 | 0 | 64 | -50 | 1.014 | 100 | 1 | 124 | 54.3 |
| 16 | 124 | 0 | 64 | -50 | 1.017 | 100 | 1 | 124 | 54.3 |
| 18 | 320 | 0 | 160 | -50 | 1.05 | 100 | 1 | 320 | 100 |
| 21 | 320 | 0 | 160 | -50 | 1.05 | 100 | 1 | 320 | 100 |
| 22 | 40 | 0 | 12.8 | -1.66667 | 1.05 | 100 | 1 | 40 | 1.666667 |
| 22 | 40 | 0 | 12.8 | -1.66667 | 1.05 | 100 | 1 | 40 | 1.666667 |
| 22 | 40 | 0 | 12.8 | -1.66667 | 1.05 | 100 | 1 | 40 | 1.666667 |
| 22 | 40 | 0 | 12.8 | -1.66667 | 1.05 | 100 | 1 | 40 | 1.666667 |
| 22 | 40 | 0 | 12.8 | -1.66667 | 1.05 | 100 | 1 | 40 | 1.666667 |
| 22 | 40 | 0 | 12.8 | -1.66667 | 1.05 | 100 | 1 | 40 | 1.666667 |
| 23 | 124 | 0 | 64 | -25 | 1.05 | 100 | 1 | 124 | 27.15 |
| 23 | 124 | 0 | 64 | -25 | 1.05 | 100 | 1 | 124 | 27.15 |
| 23 | 280 | 0 | 120 | -25 | 1.05 | 100 | 1 | 280 | 140 |

**Table B.8**

Generator data of the power transmission network in the base case [2].

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  | **ratio** | **angle** | **Status** | **angmin** | **angmax** |
| 1 | 2 | 0.0026 | 0.0139 | 0.4611 | 140 | 250 | 200 | 0 | 0 | 1 | -360 | 360 |
| 1 | 3 | 0.0546 | 0.2112 | 0.0572 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 1 | 5 | 0.0218 | 0.0845 | 0.0229 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 2 | 4 | 0.0328 | 0.1267 | 0.0343 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 2 | 6 | 0.0497 | 0.192 | 0.052 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 3 | 9 | 0.0308 | 0.119 | 0.0322 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 3 | 24 | 0.0023 | 0.0839 | 0 | 320 | 510 | 600 | 1.03 | 0 | 1 | -360 | 360 |
| 4 | 9 | 0.0268 | 0.1037 | 0.0281 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 5 | 10 | 0.0228 | 0.0883 | 0.0239 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 6 | 10 | 0.0139 | 0.0605 | 2.459 | 140 | 193 | 200 | 0 | 0 | 1 | -360 | 360 |
| 7 | 8 | 0.0159 | 0.0614 | 0.0166 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 8 | 9 | 0.0427 | 0.1651 | 0.0447 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 8 | 10 | 0.0427 | 0.1651 | 0.0447 | 140 | 208 | 220 | 0 | 0 | 1 | -360 | 360 |
| 9 | 11 | 0.0023 | 0.0839 | 0 | 320 | 510 | 600 | 1.03 | 0 | 1 | -360 | 360 |
| 9 | 12 | 0.0023 | 0.0839 | 0 | 320 | 510 | 600 | 1.03 | 0 | 1 | -360 | 360 |
| 10 | 11 | 0.0023 | 0.0839 | 0 | 320 | 510 | 600 | 1.02 | 0 | 1 | -360 | 360 |
| 10 | 12 | 0.0023 | 0.0839 | 0 | 320 | 510 | 600 | 1.02 | 0 | 1 | -360 | 360 |
| 11 | 13 | 0.0061 | 0.0476 | 0.0999 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 11 | 14 | 0.0054 | 0.0418 | 0.0879 | 400 | 625 | 625 | 0 | 0 | 1 | -360 | 360 |
| 12 | 13 | 0.0061 | 0.0476 | 0.0999 | 400 | 625 | 625 | 0 | 0 | 1 | -360 | 360 |
| 12 | 23 | 0.0124 | 0.0966 | 0.203 | 400 | 625 | 625 | 0 | 0 | 1 | -360 | 360 |
| 13 | 23 | 0.0111 | 0.0865 | 0.1818 | 400 | 625 | 625 | 0 | 0 | 1 | -360 | 360 |
| 14 | 16 | 0.005 | 0.0389 | 0.0818 | 400 | 625 | 625 | 0 | 0 | 1 | -360 | 360 |
| 15 | 16 | 0.0022 | 0.0173 | 0.0364 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 15 | 21 | 0.0063 | 0.049 | 0.103 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 15 | 21 | 0.0063 | 0.049 | 0.103 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 15 | 24 | 0.0067 | 0.0519 | 0.1091 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 16 | 17 | 0.0033 | 0.0259 | 0.0545 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 16 | 19 | 0.003 | 0.0231 | 0.0485 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 17 | 18 | 0.0018 | 0.0144 | 0.0303 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 17 | 22 | 0.0135 | 0.1053 | 0.2212 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 18 | 21 | 0.0033 | 0.0259 | 0.0545 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 18 | 21 | 0.0033 | 0.0259 | 0.0545 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 19 | 20 | 0.0051 | 0.0396 | 0.0833 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 19 | 20 | 0.0051 | 0.0396 | 0.0833 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 20 | 23 | 0.0028 | 0.0216 | 0.0455 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 20 | 23 | 0.0028 | 0.0216 | 0.0455 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |
| 21 | 22 | 0.0087 | 0.0678 | 0.1424 | 400 | 600 | 625 | 0 | 0 | 1 | -360 | 360 |

**Table B.9**

Branch data of the power transmission network in the base case [2].

**Appendix C. Correlations and Parameters for the SynGas plant**

The equations and correlations for calculating the physical properties, reaction rates, constants, and parameters are given by the equations (C.1)-(C.28) and Table C.10 [3].

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | (C.1) | | | | | | | | | |
|  | | | | (C.2) | | | | | | | | |
|  | | | | | (C.3) | | | | | | | |
|  | (C.4) | | | | | | | | | | | |
|  | | (C.5) | | | | | | | | | | |
|  | | (C.6) | | | | | | | | | | |
|  | | | | | | | | | (C.7) | | | |
|  | | | | | | | (C.8) | | | | | |
|  | | | | | | | | | (C.9) | | | |
|  | | | | | | | | | | (C.10) | | |
|  | | | | | | | | | (C.11) | | | |
|  | | | | | | | | | (C.12) | | | |
|  | | | | | | | | | (C.13) | | | |
|  | | | | | | | | | (C.14) | | | |
|  | | | | | | (C.15) | | | | | | |
|  | | | | | | | | (C.16) | | | | |
|  | | | | | | | | (C.17) | | | | |
|  | | | | | | | | | | | | (C.18) | |
|  | | | | | | | | (C.19) | | | | |
|  | | | | | | | | (C.20) | | | | |
|  | | | | | | | | (C.21) | | | | |
|  | | | | | | | | (C.22) | | | | |
|  | | | | | | | | (C.23) | | | | |
|  | | | | | | | | (C.24) | | | | |
|  | | | | | | | | (C.25) | | | | |
|  | | | | | | | | (C.26) | | | | |
|  | | | | | | | | (C.27) | | | | |
|  | | | | | | | | | | | (C.28) | |

|  |
| --- |
| Activation energies , Heat of reactions and adsorption enthalpies[] |
|  |
| 240.1 67.13 243.9 206.1 -41.15 164.9 -70.65 -82.90 -38.28 88.68 |
|  |
|  |
|  |
|  |

**Table C.10**

The kinetic data required for the reaction rates of the steam methane reforming process [3].

**References**

[1] B. Zhao, A. Zlotnik, A. J. Conejo, R. Sioshansi, and A. M. Rudkevich, "Shadow price-based co-ordination of natural gas and electric power systems," *IEEE Transactions on Power Systems,* vol. 34, no. 3, pp. 1942-1954, 2018.

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[3] G. Pantoleontos, E. S. Kikkinides, and M. C. Georgiadis, "A heterogeneous dynamic model for the simulation and optimisation of the steam methane reforming reactor," *International Journal of Hydrogen Energy,* vol. 37, no. 21, pp. 16346-16358, 2012.