**Supplementary Material**

# Novel dual-mixed refrigerant precooling process for high capacity hydrogen liquefaction plants with superior performance

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**Table S. 1**

Thermodynamic properties of each stream in the proposed process.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stream ID | Temperature | Pressure | Flow rate | Enthalpy | Entropy |
| [K] | [bar] | [kg/s] | [kJ/kg] | [kJ/kg-K] |
| HF | 298.00 | 21.00 | 3.45 | -2.83 | 48.47 |
| 1 | 250.00 | 21.00 | 3.45 | -682.59 | 45.99 |
| 2 | 215.00 | 21.00 | 3.45 | -1178.05 | 43.85 |
| 3 | 133.00 | 21.00 | 3.45 | -2344.28 | 37.01 |
| 4 | 81.00 | 21.00 | 3.45 | -3105.32 | 29.73 |
| 5 | 296.18 | 3.10 | 47.50 | -1876.47 | 4.42 |
| 6 | 326.05 | 6.00 | 47.50 | -1829.40 | 4.43 |
| 7 | 294.00 | 6.00 | 47.50 | -1991.84 | 3.90 |
| 8 | 317.64 | 11.90 | 47.50 | -1954.68 | 3.91 |
| 9 | 294.00 | 11.90 | 47.50 | -2167.01 | 3.21 |
| 10 | 294.00 | 11.90 | 15.77 | -1433.68 | 5.35 |
| 11 | 250.00 | 11.90 | 15.77 | -2003.28 | 3.26 |
| 12 | 214.00 | 11.90 | 15.77 | -2101.23 | 2.84 |
| 13 | 212.92 | 3.10 | 15.77 | -2101.23 | 2.84 |
| 14 | 249.81 | 3.10 | 15.77 | -1520.59 | 5.36 |
| 15 | 294.00 | 11.90 | 31.73 | -2531.52 | 2.15 |
| 16 | 250.00 | 11.90 | 31.73 | -2642.99 | 1.74 |
| 17 | 250.23 | 5.09 | 31.73 | -2642.99 | 1.74 |
| 18 | 248.33 | 3.10 | 47.50 | -2270.32 | 2.95 |
| 19 | 212.84 | 4.70 | 33.00 | -1030.37 | 6.53 |
| 20 | 319.30 | 25.00 | 33.00 | -874.04 | 6.58 |
| 21 | 294.00 | 25.00 | 33.00 | -919.60 | 6.44 |
| 22 | 312.72 | 32.00 | 33.00 | -893.27 | 6.44 |
| 23 | 294.00 | 32.00 | 33.00 | -927.97 | 6.33 |
| 24 | 309.13 | 39.00 | 33.00 | -907.50 | 6.34 |
| 25 | 294.00 | 39.00 | 33.00 | -936.48 | 6.24 |
| 26 | 250.00 | 39.00 | 33.00 | -1052.93 | 5.80 |
| 27 | 215.00 | 39.00 | 33.00 | -1231.82 | 5.03 |
| 28 | 215.00 | 39.00 | 19.42 | -1397.28 | 5.94 |
| 29 | 133.00 | 39.00 | 19.42 | -1790.51 | 3.67 |
| 30 | 81.00 | 39.00 | 19.42 | -1918.22 | 2.46 |
| 31 | 80.90 | 1.00 | 19.42 | -1918.22 | 2.54 |
| 32 | 129.36 | 4.70 | 19.42 | -1655.33 | 4.93 |
| 33 | 215.00 | 39.00 | 13.58 | -995.20 | 3.73 |
| 34 | 133.00 | 39.00 | 13.58 | -1199.73 | 2.54 |
| 35 | 132.48 | 4.70 | 13.58 | -1199.73 | 2.59 |
| 36 | 132.28 | 4.70 | 33.00 | -1467.84 | 3.98 |

**Table S. 2**

Exergy destruction rate and exergy efficiency of the proposed DMR equipment.

|  |  |  |
| --- | --- | --- |
| Components | Irreversibility | Exergy efficiency (ε) |
| [MW] | [%] |
| HX1 | 0.70 | 88.00 |
| HX2 | 0.24 | 92.00 |
| HX3 | 0.28 | 89.99 |
| HX4 | 0.19 | 88.04 |
| MRC1 | 0.23 | 88.99 |
| MRC2 | 0.23 | 88.99 |
| MRC3 | 0.14 | 87.96 |
| MRC4 | 0.14 | 88.49 |
| MRC5 | 0.12 | 90.00 |
| CL1 | 0.38 | 81.99 |
| CL2 | 0.43 | 79.99 |
| CL3 | 0.18 | 85.00 |
| CL4 | 0.16 | 86.00 |
| CL5 | 0.15 | 87.00 |
| EV1 | 0.26 | 82.00 |
| EV2 | 0.13 | 81.00 |
| EV3 | 0.12 | 79.98 |
| EV4 | 0.12 | 78.94 |
| M1 | 0.00 | 100.00 |
| M2 | 0.00 | 99.99 |
| S1 | 0.00 | 100.00 |
| S2 | 0.00 | 100.00 |

**Table S. 3**

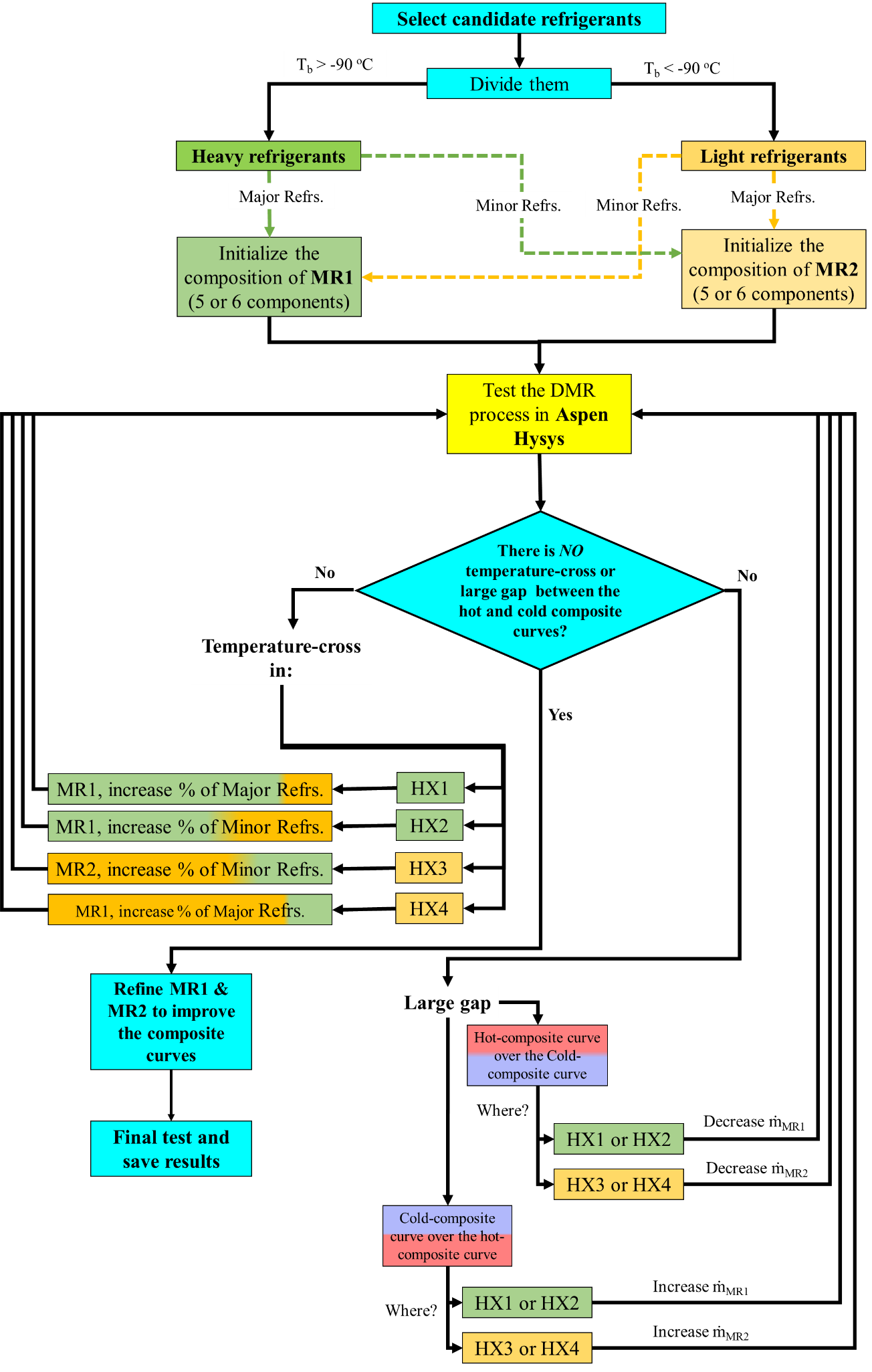
Breakdown of the equipment costs of the reference SMR process. Note: miscellaneous components such as mixers and separators were taken as 1.00% of the total cost of the other equipment.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Component | K1 | K2 | K3 | Ep, [$] | FPM | CBM, [$] |
| HX1 | 4.6656 | -0.1557 | 0.1547 | 1.545E+06 | 1 | 1.545E+06 |
| HX2 | 4.6656 | -0.1557 | 0.1547 | 1.155E+06 | 1 | 1.155E+06 |
| HX3 | 4.6656 | -0.1557 | 0.1547 | 8.033E+05 | 1 | 8.033E+05 |
| MRC1 | 2.2897 | 1.3604 | -0.1027 | 1.124E+06 | 1 | 1.124E+06 |
| MRC2 | 2.2897 | 1.3604 | -0.1027 | 8.129E+05 | 1 | 8.129E+05 |
| Pump-1 | 2.2897 | 1.3604 | -0.1027 | 8.958E+03 | 1 | 8.958E+03 |
| CL1 | 4.3247 | -0.303 | 0.1634 | 7.369E+05 | 1 | 7.369E+05 |
| CL2 | 4.3247 | -0.303 | 0.1634 | 5.397E+05 | 1 | 5.397E+05 |
| Exp-1 | 2.2476 | 1.4956 | -0.1618 | 2.770E+04 | 1 | 2.770E+04 |
| Exp-2 | 2.2476 | 1.4956 | -0.1618 | 2.368E+04 | 1 | 2.368E+04 |
| Exp-3 | 2.2476 | 1.4956 | -0.1618 | 3.168E+04 | 1 | 3.168E+04 |

**Table S. 4**

Breakdown of the equipment costs of the proposed DMR process. Note: miscellaneous components such as mixers and separators were taken as 2.00% of the total cost of the other equipment.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Component | K1 | K2 | K3 | Ep, [$] | FPM | CBM, [$] |
| HX1 | 4.6656 | -0.1557 | 0.1547 | 7.818E+05 | 1 | 7.818E+05 |
| HX2 | 4.6656 | -0.1557 | 0.1547 | 7.279E+05 | 1 | 7.279E+05 |
| HX3 | 4.6656 | -0.1557 | 0.1547 | 7.542E+05 | 1 | 7.542E+05 |
| HX4 | 4.6656 | -0.1557 | 0.1547 | 3.516E+05 | 1 | 3.516E+05 |
| MRC1 | 2.2897 | 1.3604 | -0.1027 | 4.945E+05 | 1 | 4.945E+05 |
| MRC2 | 2.2897 | 1.3604 | -0.1027 | 4.207E+05 | 1 | 4.207E+05 |
| MRC3 | 2.2897 | 1.3604 | -0.1027 | 8.409E+05 | 1 | 8.409E+05 |
| MRC4 | 2.2897 | 1.3604 | -0.1027 | 2.516E+05 | 1 | 2.516E+05 |
| MRC5 | 2.2897 | 1.3604 | -0.1027 | 2.073E+05 | 1 | 2.073E+05 |
| CL1 | 4.3247 | -0.303 | 0.1634 | 4.131E+05 | 1 | 4.131E+05 |
| CL2 | 4.3247 | -0.303 | 0.1634 | 5.381E+05 | 1 | 5.381E+05 |
| CL3 | 4.3247 | -0.303 | 0.1634 | 1.026E+05 | 1 | 1.026E+05 |
| CL4 | 4.3247 | -0.303 | 0.1634 | 8.447E+04 | 1 | 8.447E+04 |
| CL5 | 4.3247 | -0.303 | 0.1634 | 7.467E+04 | 1 | 7.467E+04 |



**Fig. S. 1.** Flowchart of the applied step to determine the composition of MR1 and MR2.