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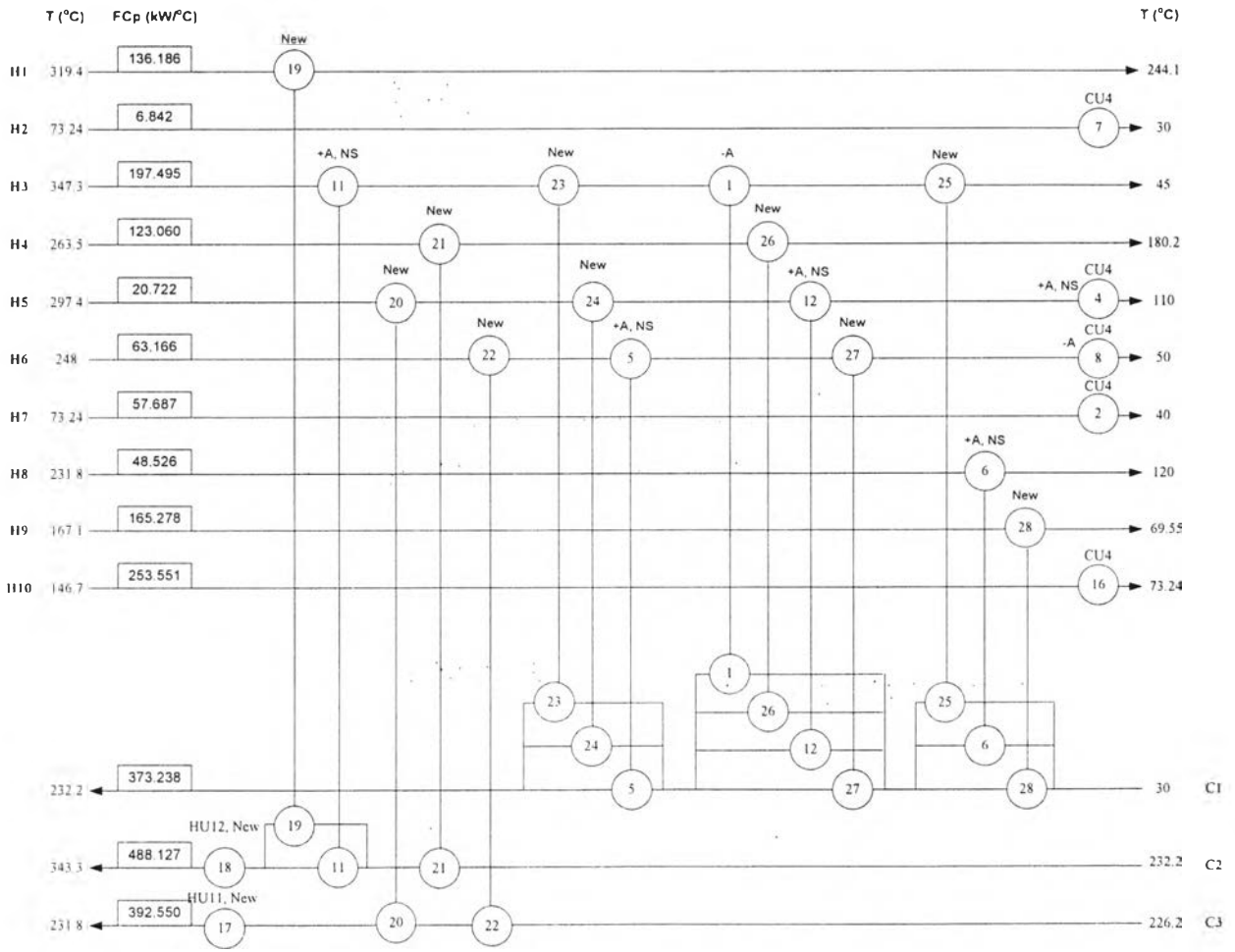
# APPENDICES

## Appendix A Collecting Process Data for Example 2

### A1 1st Alternative Design

**Table A1** Retrofitted heat exchanger results (1st alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 14977.38 | 3447.87 | -855.33 | Area reduction |
| 2 | 63.8 | 1917.53 | 63.80 | 0.00 | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | 1400.29 | 13.01 | 8.95 | Area addition (new shell) |
| 5 | 26.79 | 316.104 | 46.19 | 19.40 | Area addition (new shell) |
| 6 | 24.6 | 5425.194 | 152.67 | 128.07 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | 7160.66 | 111.17 | -35.42 | Area reduction |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | - | - | - | - |
| 11 | 658.7 | 20164.21 | 2287.66 | 1628.96 | Area addition (new shell) |
| 12 | 40 | 1277.033 | 166.97 | 126.97 | Area addition (new shell) |
| 13 | 182.39 | - | - | - | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | 18625.861 | 288.97 | 0.00 | - |
| 17 | 52.24 | 752.485 | 17.18 | -35.06 | New exchanger |
| 18 | 976.4 | 21559.853 | 575.45 | -400.95 | New exchanger |
| 19 | - | 10254.833 | 1651.47 | - | New exchanger |
| 20 | - | 889.935 | 22.08 | - | New exchanger |
| 21 | - | 2251.997 | 237.33 | - | New exchanger |
| 22 | - | 555.858 | 37.01 | - | New exchanger |
| 23 | - | 1184.968 | 272.79 | - | New exchanger |
| 24 | - | 738.359 | 137.24 | - | New exchanger |
| 25 | - | 23376.088 | 4072.08 | - | New exchanger |
| 26 | - | 7260.534 | 865.66 | - | New exchanger |
| 27 | - | 4790.288 | 926.55 | - | New exchanger |
| 28 | - | 16122.861 | 1464.57 | - | New exchanger |



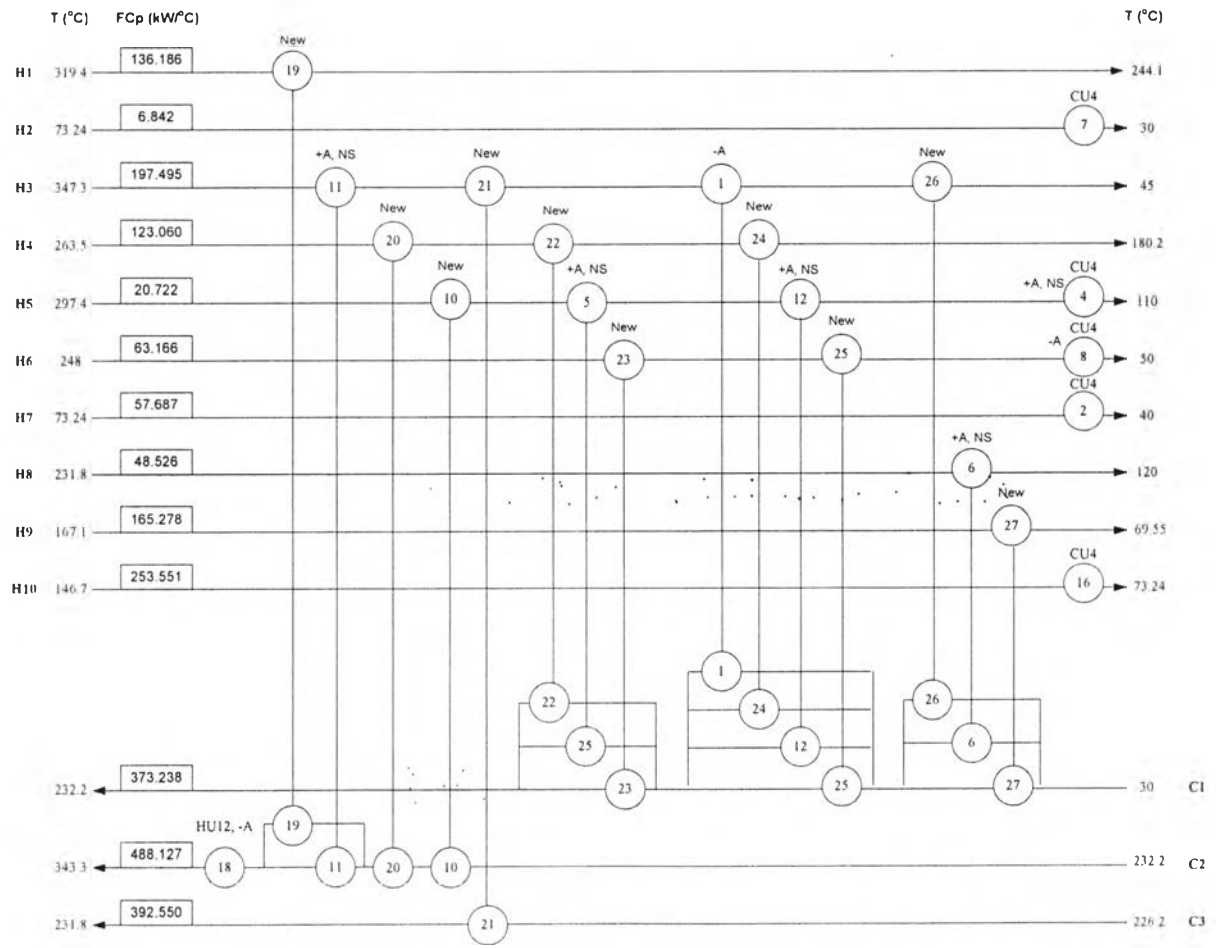

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A1** Retrofitted heat exchanger results (1st alternative design at $\Delta T_{min} = 13\ ^{o}C$).

A2 2nd Alternative Design

**Table A2** Retrofitted heat exchanger results (2nd alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 14977.38 | 3447.87 | -855.33 | Area reduction |
| 2 | 63.8 | 1917.53 | 63.80 | 0.00 | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | 1400.29 | 13.01 | 8.95 | Area addition (new shell) |
| 5 | 26.79 | 945.214 | 83.91 | 57.12 | Area addition (new shell) |
| 6 | 24.6 | 5425.194 | 152.67 | 128.07 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | 7160.66 | 111.17 | -35.42 | Area reduction |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | 260.83 | 9.11 | -71.09 | New exchanger |
| 11 | 658.7 | 19150.90 | 1807.45 | 1148.75 | Area addition (new shell) |
| 12 | 40 | 1277.033 | 166.97 | 126.97 | Area addition (new shell) |
| 13 | 182.39 | - | - | - | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | 18625.861 | 288.97 | 0.00 | - |
| 17 | 52.24 | - | - | - | - |
| 18 | 976.4 | 22312.338 | 593.70 | -382.70 | Area reduction |
| 19 | - | 10254.833 | 1631.80 | - | New exchanger |
| 20 | - | 2251.997 | 244.50 | - | New exchanger |
| 21 | - | 2198.278 | 221.37 | - | New exchanger |
| 22 | - | 738.359 | 137.24 | - | New exchanger |
| 23 | - | 555.858 | 97.37 | - | New exchanger |
| 24 | - | 7260.534 | 865.66 | - | New exchanger |
| 25 | - | 4790.288 | 926.55 | - | New exchanger |
| 26 | - | 23376.088 | 4072.08 | - | New exchanger |
| 27 | - | 16122.861 | 1464.57 | - | New exchanger |



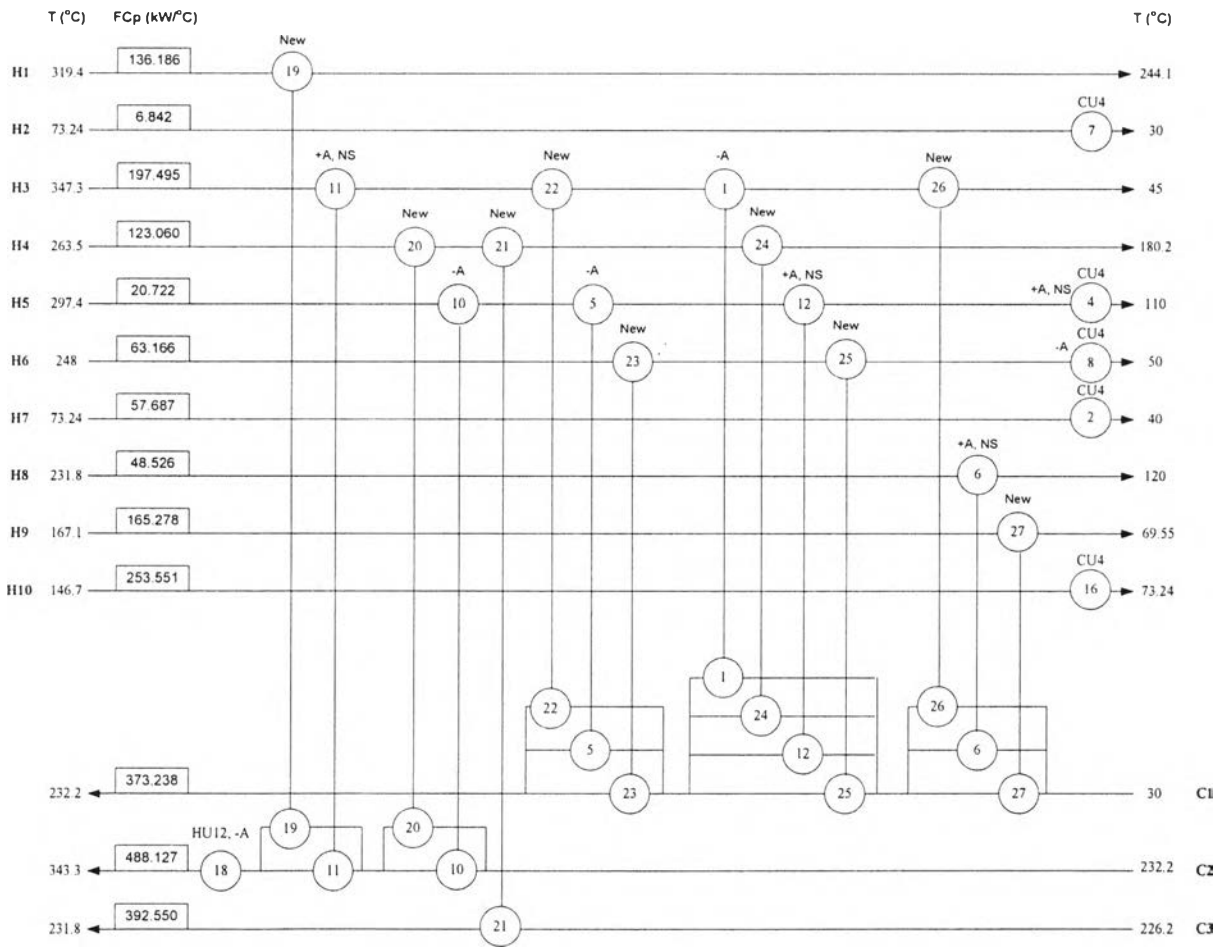

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A2** Retrofitted heat exchanger results (2nd alternative design at $\Delta T_{min} = 13\ ^{o}$).

## A3 3rd Alternative Design

**Table A3** Retrofitted heat exchanger results (3rd alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 14977.38 | 3447.87 | -855.33 | Area reduction |
| 2 | 63.8 | 1917.53 | 63.80 | 0.00 | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | 1400.29 | 13.01 | 8.95 | Area addition (new shell) |
| 5 | 26.79 | 124.334 | 24.06 | -2.73 | Area reduction |
| 6 | 24.6 | 5425.194 | 152.67 | 128.07 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | 7160.66 | 111.17 | -35.42 | Area reduction |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | 1081.71 | 70.81 | -9.39 | Area reduction |
| 11 | 658.7 | 19789.94 | 1987.03 | 1328.33 | Area addition (new shell) |
| 12 | 40 | 1277.033 | 166.97 | 126.97 | Area addition (new shell) |
| 13 | 182.39 | - | - | - | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | 18625.861 | 288.97 | 0.00 | - |
| 17 | 52.24 | - | - | - | - |
| 18 | 976.4 | 22312.338 | 593.70 | -382.70 | Area reduction |
| 19 | - | 10254.833 | 1517.08 | - | New exchanger |
| 20 | - | 792.078 | 60.77 | - | New exchanger |
| 21 | - | 2198.278 | 187.13 | - | New exchanger |
| 22 | - | 1559.239 | 270.54 | - | New exchanger |
| 23 | - | 555.858 | 97.37 | - | New exchanger |
| 24 | - | 7260.534 | 865.66 | - | New exchanger |
| 25 | - | 4790.288 | 926.55 | - | New exchanger |
| 26 | - | 23376.088 | 4072.08 | - | New exchanger |
| 27 | - | 16122.861 | 1464.57 | - | New exchanger |



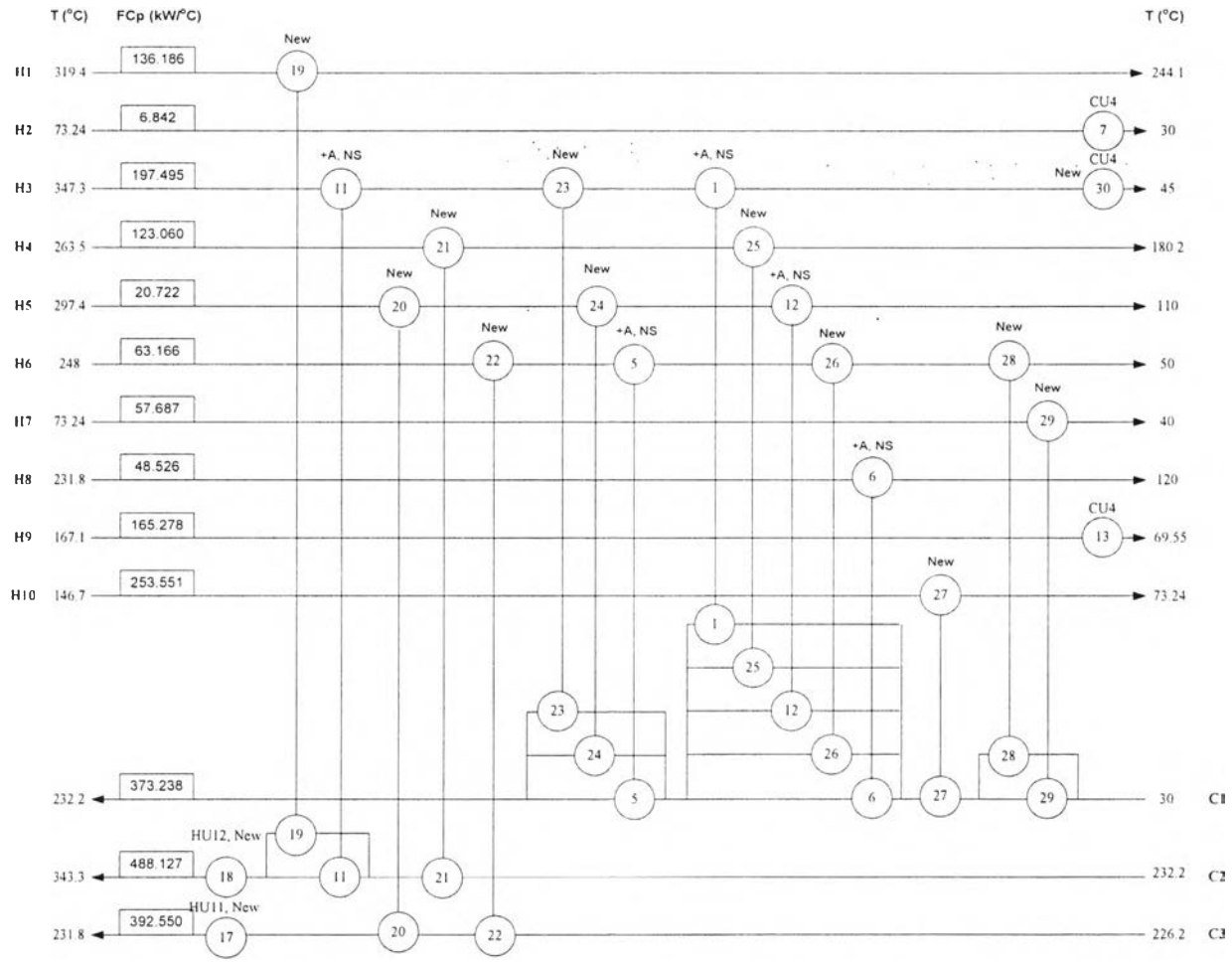

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A3** Retrofitted heat exchanger results (3rd alternative design at $\Delta T_{min} = 13^{o}C$).

## A4 4th Alternative Design

**Table A4** Retrofitted heat exchanger results (4th alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 25371.99 | 5271.72 | 968.52 | Area addition (new shell) |
| 2 | 63.8 | - | - | - | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | - | - | - | - |
| 5 | 26.79 | 316.104 | 46.19 | 19.40 | Area addition (new shell) |
| 6 | 24.6 | 5425.194 | 1004.10 | 979.50 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | - | - | - | - |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | - | - | - | - |
| 11 | 658.7 | 20164.21 | 2287.66 | 1628.96 | Area addition (new shell) |
| 12 | 40 | 2677.323 | 479.03 | 439.03 | Area addition (new shell) |
| 13 | 182.39 | 16122.861 | 182.39 | 0.00 | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | - | - | - | - |
| 17 | 52.24 | 752.485 | 17.18 | -35.06 | New exchanger |
| 18 | 976.4 | 21559.853 | 575.45 | -400.95 | New exchanger |
| 19 | - | 10254.833 | 1651.47 | - | New exchanger |
| 20 | - | 889.935 | 22.08 | - | New exchanger |
| 21 | - | 2251.997 | 237.33 | - | New exchanger |
| 22 | - | 555.858 | 37.01 | - | New exchanger |
| 23 | - | 1184.968 | 272.79 | - | New exchanger |
| 24 | - | 738.359 | 137.24 | - | New exchanger |
| 25 | - | 7260.534 | 713.14 | - | New exchanger |
| 26 | - | 8298.236 | 1605.07 | - | New exchanger |
| 27 | - | 18625.861 | 1233.17 | - | New exchanger |
| 28 | - | 3652.711 | 245.31 | - | New exchanger |
| 29 | | 1917.528 | 268.32 | - | New exchanger |
| 30 | | 12981.477 | 415.85 | - | New exchanger |



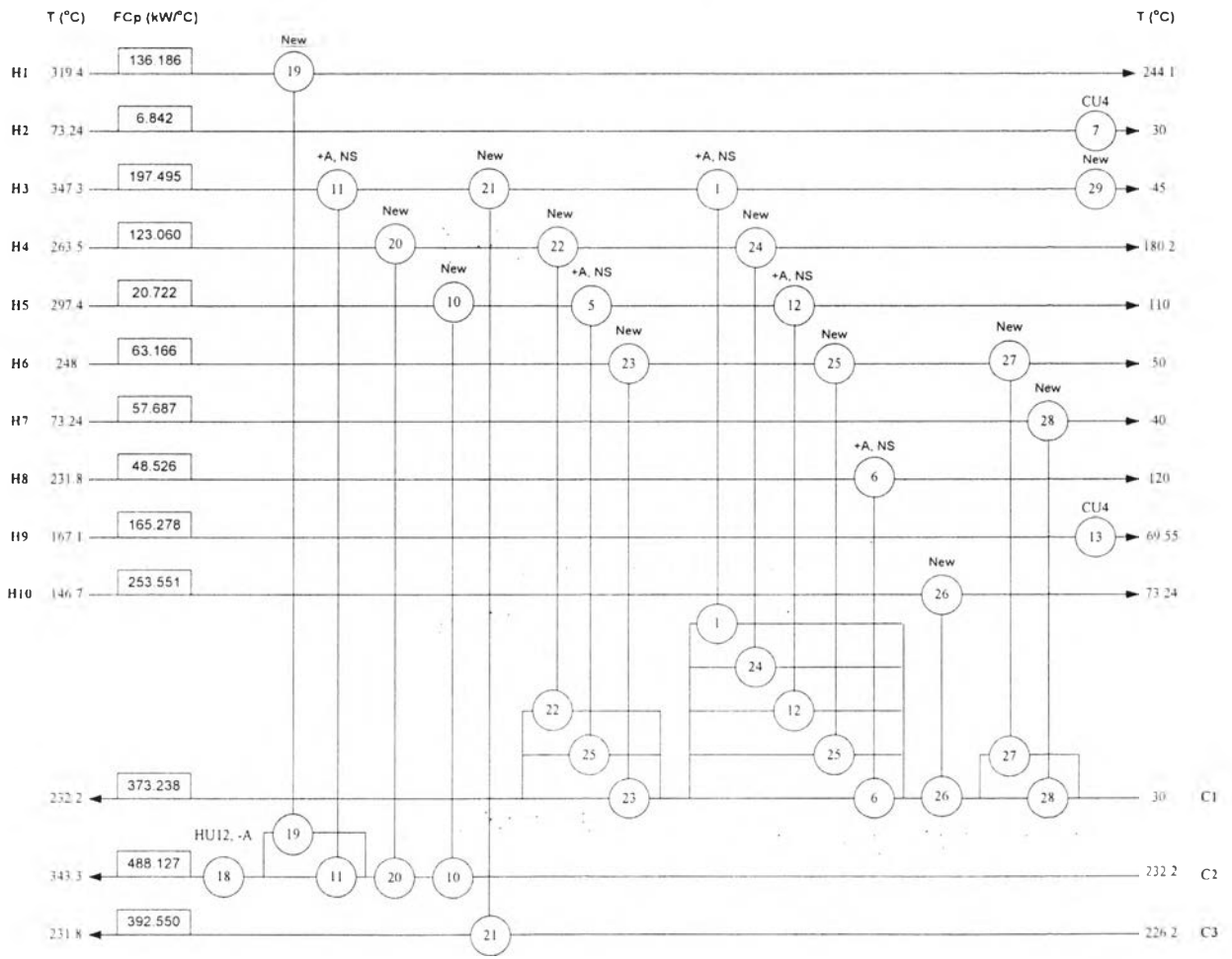

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A4** Retrofitted heat exchanger results ($4^{th}$ alternative design at $\Delta T_{min} = 13\ ^{o}$).

## A5 5th Alternative Design

**Table A5** Retrofitted heat exchanger results (5th alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 25371.99 | 5271.72 | 968.52 | Area addition (new shell) |
| 2 | 63.8 | - | - | - | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | - | - | - | - |
| 5 | 26.79 | 945.214 | 83.91 | 57.12 | Area addition (new shell) |
| 6 | 24.6 | 5425.194 | 1004.10 | 979.50 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | - | - | - | - |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | 260.83 | 9.11 | -71.09 | New exchanger |
| 11 | 658.7 | 19150.90 | 1807.45 | 1148.75 | Area addition (new shell) |
| 12 | 40 | 2677.323 | 479.03 | 439.03 | Area addition (new shell) |
| 13 | 182.39 | 16122.861 | 182.39 | 0.00 | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | - | - | - | - |
| 17 | 52.24 | - | - | - | - |
| 18 | 976.4 | 22312.338 | 593.70 | -382.70 | Area reduction |
| 19 | - | 10254.833 | 1631.80 | - | New exchanger |
| 20 | - | 2251.997 | 244.50 | - | New exchanger |
| 21 | - | 2198.278 | 221.37 | - | New exchanger |
| 22 | - | 738.359 | 137.24 | - | New exchanger |
| 23 | - | 555.858 | 97.37 | - | New exchanger |
| 24 | - | 7260.534 | 456.23 | - | New exchanger |
| 25 | - | 8298.236 | 1605.07 | - | New exchanger |
| 26 | - | 18625.861 | 1174.78 | - | New exchanger |
| 27 | - | 3652.711 | 245.31 | - | New exchanger |
| 28 | - | 1917.528 | 268.32 | - | New exchanger |
| 29 | - | 12981.477 | 415.85 | - | New exchanger |



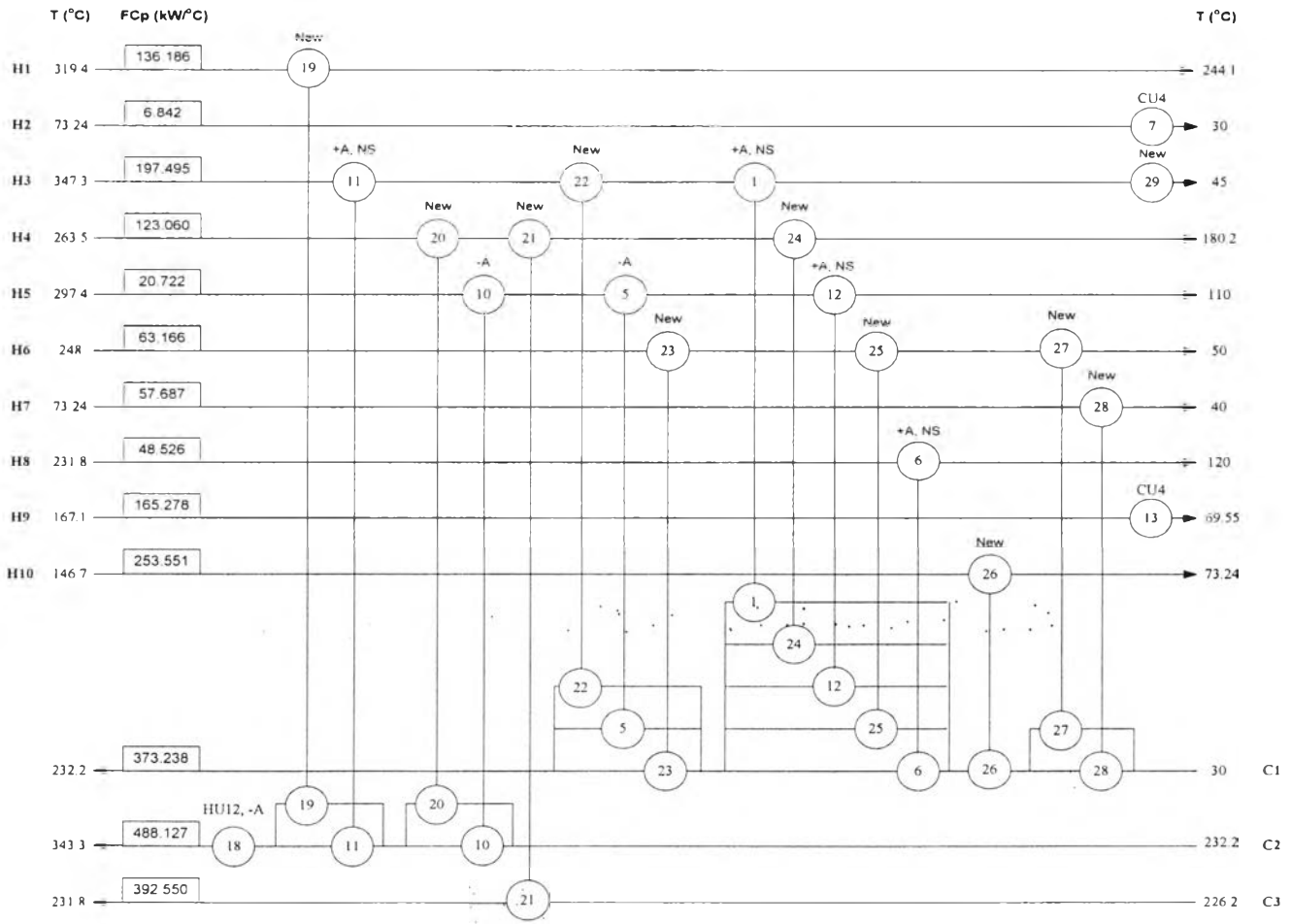

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A5** Retrofitted heat exchanger results ($5^{th}$ alternative design at $\Delta T_{min} = 13\ ^{o}$).

## A6 6th Alternative Design

**Table A6** Retrofitted heat exchanger results (6th alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | Remarks |
|---|---|---|---|---|---|
| 1 | 4303.20 | 25371.99 | 5271.72 | 968.52 | Area addition (new shell) |
| 2 | 63.80 | - | - | - | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | - | - | - | - |
| 5 | 26.79 | 124.33 | 24.06 | -2.73 | Area reduction |
| 6 | 24.60 | 5425.19 | 1004.10 | 979.50 | Area addition (new shell) |
| 7 | 5.87 | 295.83 | 5.87 | 0.00 | - |
| 8 | 146.59 | - | - | - | - |
| 9 | 1214.40 | - | - | - | - |
| 10 | 80.20 | 1081.71 | 70.81 | -9.39 | Area reduction |
| 11 | 658.70 | 19789.94 | 1987.03 | 1328.33 | Area addition (new shell) |
| 12 | 40.00 | 2677.32 | 479.03 | 439.03 | Area addition (new shell) |
| 13 | 182.39 | 16122.86 | 182.39 | 0.00 | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | - | - | - | - |
| 17 | 52.24 | - | - | - | - |
| 18 | 976.40 | 22312.34 | 593.70 | -382.70 | Area reduction |
| 19 | - | 10254.83 | 1517.08 | - | New exchanger |
| 20 | - | 792.08 | 60.77 | - | New exchanger |
| 21 | - | 2198.28 | 118.48 | - | New exchanger |
| 22 | - | 1559.24 | 335.08 | - | New exchanger |
| 23 | - | 555.86 | 97.37 | - | New exchanger |
| 24 | - | 7260.53 | 456.23 | - | New exchanger |
| 25 | - | 8298.24 | 1605.07 | - | New exchanger |
| 26 | - | 18625.86 | 1233.17 | - | New exchanger |
| 27 | - | 3652.71 | 245.31 | - | New exchanger |
| 28 | - | 1917.53 | 268.32 | - | New exchanger |
| 29 | - | 12981.48 | 415.85 | - | New exchanger |



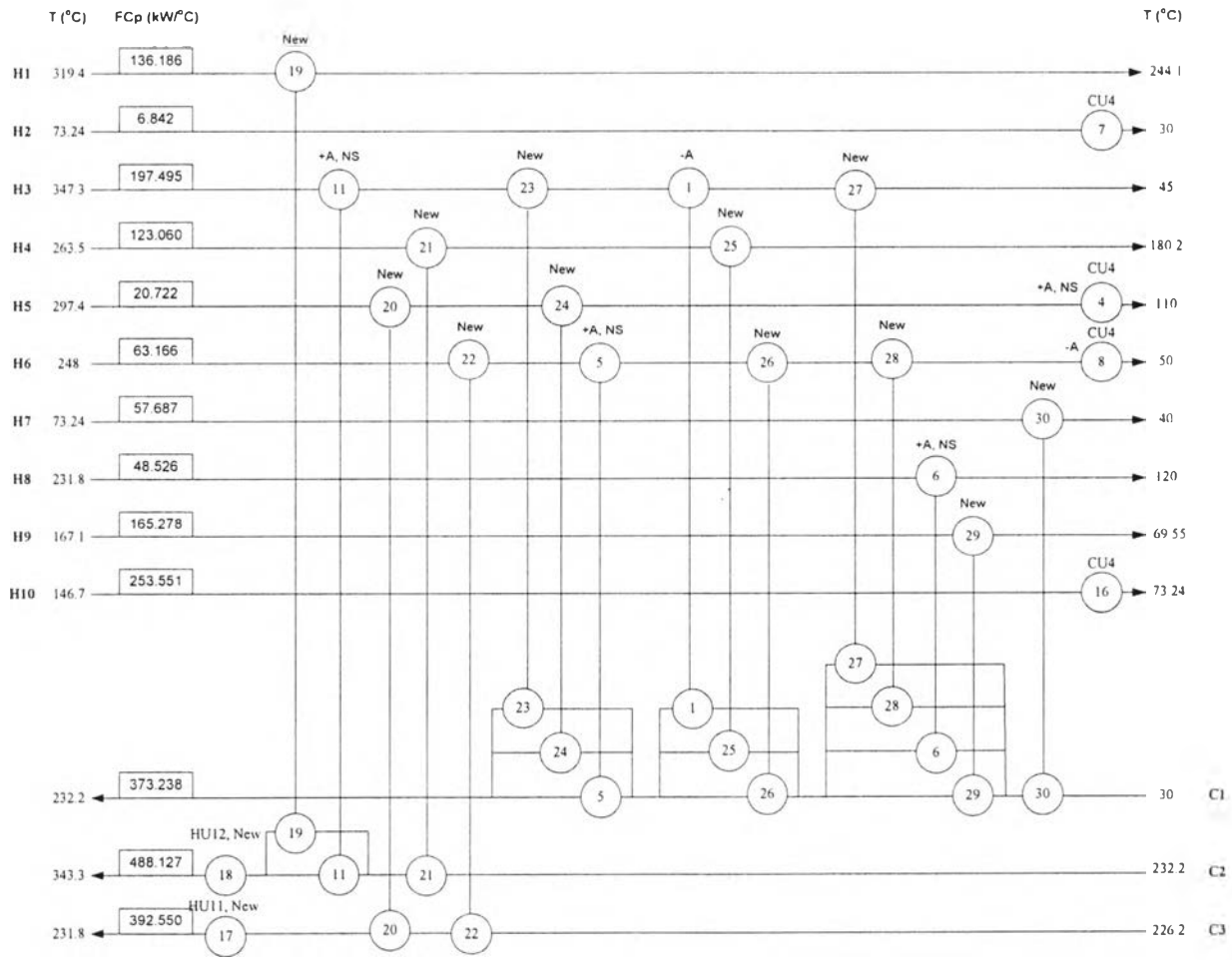

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A6** Retrofitted heat exchanger results ($6^{th}$ alternative design at $\Delta T_{min} = 13\ ^{\circ}C$).

A7 7th Alternative Design

**Table A7** Retrofitted heat exchanger results (7th alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 12659.41 | 2914.26 | -1388.94 | Area reduction |
| 2 | 63.8 | - | - | - | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | 2677.32 | 20.59 | 16.53 | Area addition (new shell) |
| 5 | 26.79 | - | - | - | - |
| 6 | 24.6 | 5425.194 | 169.75 | 145.15 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | 7801.15 | 115.87 | -30.72 | Area reduction |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | - | - | - | - |
| 11 | 658.7 | 20164.21 | 2287.66 | 1628.96 | Area addition (new shell) |
| 12 | 40 | - | - | - | - |
| 13 | 182.39 | - | - | - | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | 18625.861 | 288.97 | 0.00 | - |
| 17 | 52.24 | 752.485 | 17.18 | -35.06 | New exchanger |
| 18 | 976.4 | 21559.853 | 575.45 | -400.95 | New exchanger |
| 19 | - | 10254.833 | 1651.47 | - | New exchanger |
| 20 | - | 889.935 | 22.08 | - | New exchanger |
| 21 | - | 2251.997 | 237.33 | - | New exchanger |
| 22 | - | 555.858 | 37.01 | - | New exchanger |
| 23 | - | 1184.968 | 272.79 | - | New exchanger |
| 24 | - | 738.359 | 137.24 | - | New exchanger |
| 25 | - | 7260.534 | 1138.48 | - | New exchanger |
| 26 | - | 4004.64 | 754.42 | - | New exchanger |
| 27 | - | 25694.057 | 6769.50 | - | New exchanger |
| 28 | - | 145.153 | 6.77 | - | New exchanger |
| 29 | | 16122.861 | 2548.13 | - | New exchanger |
| 30 | | 1917.528 | 224.76 | - | New exchanger |



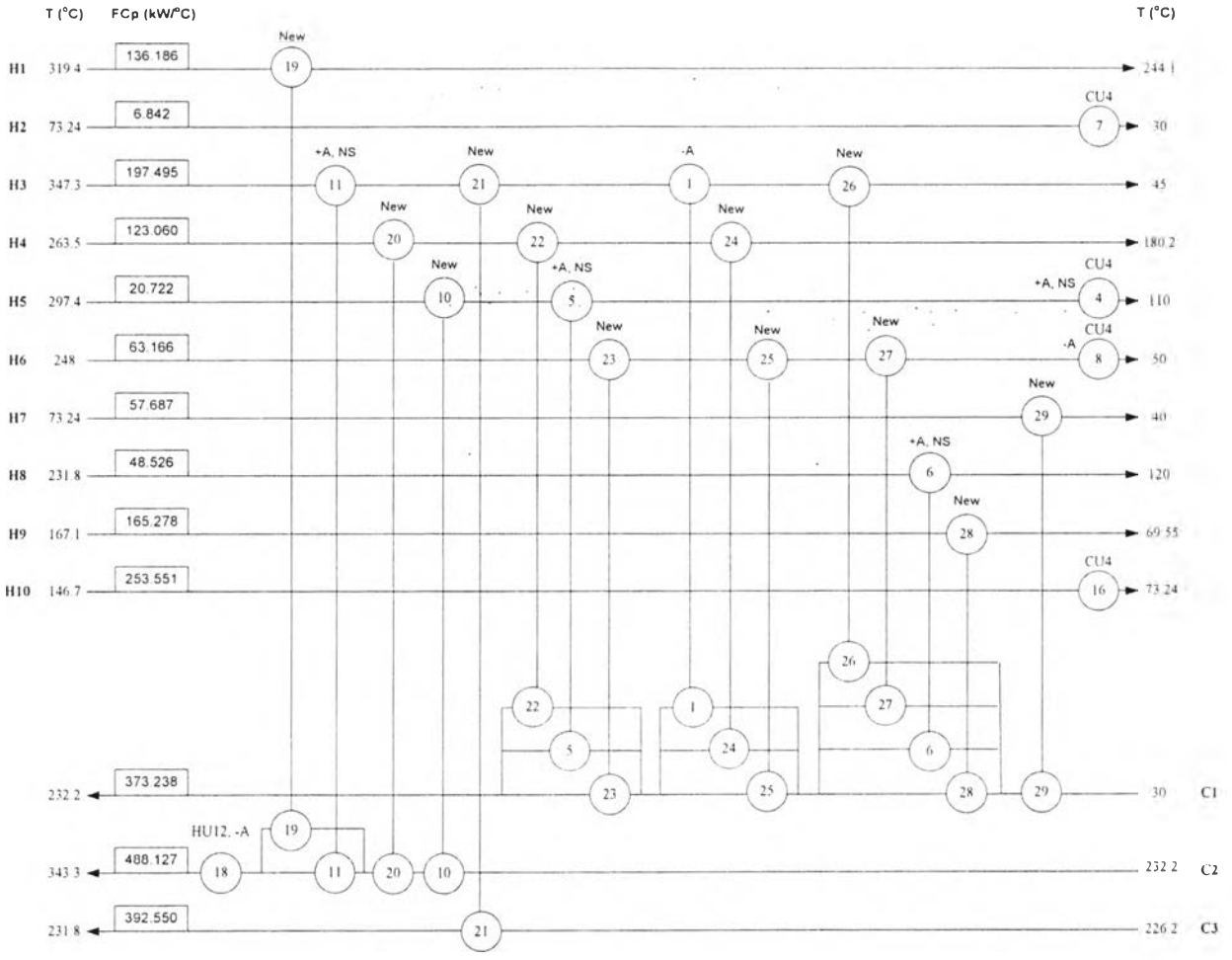

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A7** Retrofitted heat exchanger results ($7^{th}$ alternative design at $\Delta T_{min} = 13\ ^{o}$).

## A8 8th Alternative Design

**Table A8** Retrofitted heat exchanger results (8th alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change (m2) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 12659.41 | 2914.26 | -1388.94 | Area reduction |
| 2 | 63.8 | - | - | - | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | 2677.32 | 20.59 | 16.53 | Area addition (new shell) |
| 5 | 26.79 | 945.214 | 83.91 | 57.12 | Area addition (new shell) |
| 6 | 24.6 | 5425.194 | 169.75 | 145.15 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | 7801.15 | 115.87 | -30.72 | Area reduction |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | 260.83 | 9.11 | -71.09 | New exchanger |
| 11 | 658.7 | 19150.90 | 1807.45 | 1148.75 | Area addition (new shell) |
| 12 | 40 | - | - | - | - |
| 13 | 182.39 | - | - | - | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | 18625.861 | 288.97 | 0.00 | - |
| 17 | 52.24 | - | - | - | - |
| 18 | 976.4 | 22312.338 | 593.70 | -382.70 | Area reduction |
| 19 | - | 10254.833 | 1631.80 | - | New exchanger |
| 20 | - | 2251.997 | 244.50 | - | New exchanger |
| 21 | - | 2198.278 | 221.37 | - | New exchanger |
| 22 | - | 738.359 | 137.24 | - | New exchanger |
| 23 | - | 555.858 | 97.37 | - | New exchanger |
| 24 | - | 7260.534 | 1138.48 | - | New exchanger |
| 25 | - | 4004.64 | 754.42 | - | New exchanger |
| 26 | - | 25694.057 | 6769.50 | - | New exchanger |
| 27 | - | 145.153 | 6.77 | - | New exchanger |
| 28 | - | 16122.861 | 2548.13 | - | New exchanger |
| 29 | - | 1917.528 | 224.76 | - | New exchanger |



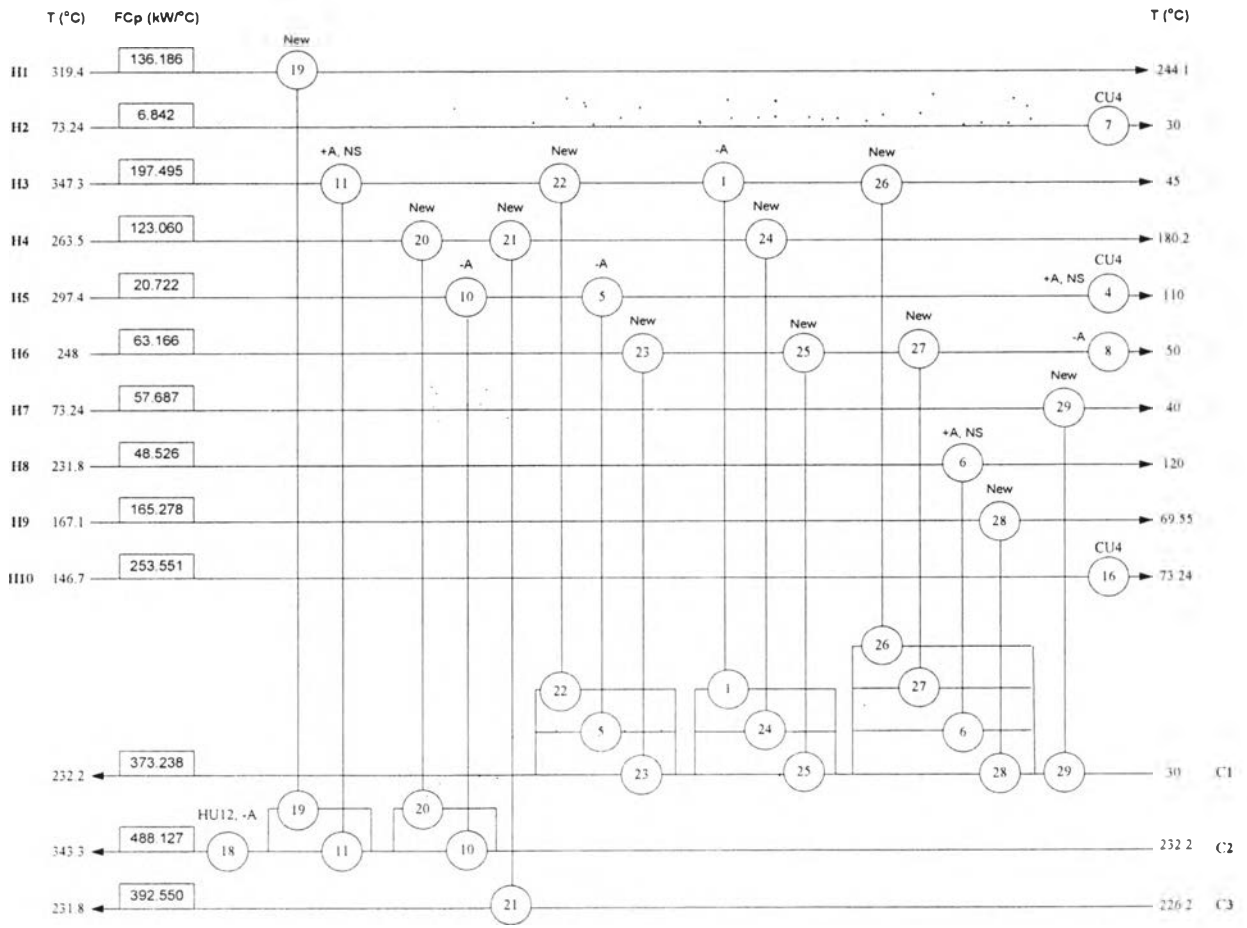

**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A8** Retrofitted heat exchanger results ($8^{th}$ alternative design at $\Delta T_{min} = 13\ ^{o}$).

A9 9th Alternative Design

**Table A9** Retrofitted heat exchanger results (9th alternative design at $\Delta T_{min} = 13\ ^{o}C$)

| Heat Exchanger | Original area ($m^2$) | Load after retrofit (kW) | Retrofit area ($m^2$) | Area change ($m^2$) | |
|---|---|---|---|---|---|
| 1 | 4303.2 | 12659.41 | 2914.26 | -1388.94 | Area reduction |
| 2 | 63.8 | - | - | - | - |
| 3 | 33.29 | - | - | - | - |
| 4 | 4.06 | 2677.32 | 20.59 | 16.53 | Area addition (new shell) |
| 5 | 26.79 | 124.334 | 24.06 | -2.73 | Area reduction |
| 6 | 24.6 | 5425.194 | 169.75 | 145.15 | Area addition (new shell) |
| 7 | 5.87 | 295.833 | 5.87 | 0.00 | - |
| 8 | 146.59 | 7801.15 | 115.87 | -30.72 | Area reduction |
| 9 | 1214.4 | - | - | - | - |
| 10 | 80.2 | 1081.71 | 70.81 | -9.39 | Area reduction |
| 11 | 658.7 | 19789.94 | 1987.03 | 1328.33 | Area addition (new shell) |
| 12 | 40 | - | - | - | - |
| 13 | 182.39 | - | - | - | - |
| 14 | 101.47 | - | - | - | - |
| 15 | 93.87 | - | - | - | - |
| 16 | 288.97 | 18625.861 | 288.97 | 0.00 | - |
| 17 | 52.24 | - | - | - | - |
| 18 | 976.4 | 22312.338 | 593.70 | -382.70 | Area reduction |
| 19 | - | 10254.833 | 1517.08 | - | New exchanger |
| 20 | - | 792.078 | 60.77 | - | New exchanger |
| 21 | - | 2198.278 | 118.48 | - | New exchanger |
| 22 | - | 1559.239 | 335.08 | - | New exchanger |
| 23 | - | 555.858 | 97.37 | - | New exchanger |
| 24 | - | 7260.534 | 1138.48 | - | New exchanger |
| 25 | - | 4004.64 | 754.42 | - | New exchanger |
| 26 | - | 25694.057 | 6769.50 | - | New exchanger |
| 27 | - | 145.153 | 6.77 | - | New exchanger |
| 28 | - | 16122.861 | 2548.13 | - | New exchanger |
| 29 | - | 1917.528 | 224.76 | - | New exchanger |




**Notation**: New exchanger (New), Area addition (+A); New shell (NS), Area reduction (-A)

**Figure A9** Retrofitted heat exchanger results ($9^{th}$ alternative design at $\Delta T_{min} = 13\ ^{o}$).

## Appendix B Manual for Grassroots and Retrofit Potential Programs

### B1 Potential Grassroots Program

#### *B1.1 Background*

So far the use of Pinch Analysis has been considered for setting the energy targets for a process. These targets are dependent on the choice of the $DT_{min}$ for the process. Lowering the value of $DT_{min}$ lowers the target for minimum energy consumption for the process.

For certain types of applications such as refinery crude preheat trains, where there are few matching constraints between hot and cold streams; it is possible to set capital cost targets in addition to the energy targets. This allows the consideration of the trade-offs between capital and energy in order to obtain an optimum value of $DT_{min}$ ahead of network design.

#### *B1.2 MS office incorporated with Visual Basic for Application (VBA) Program*

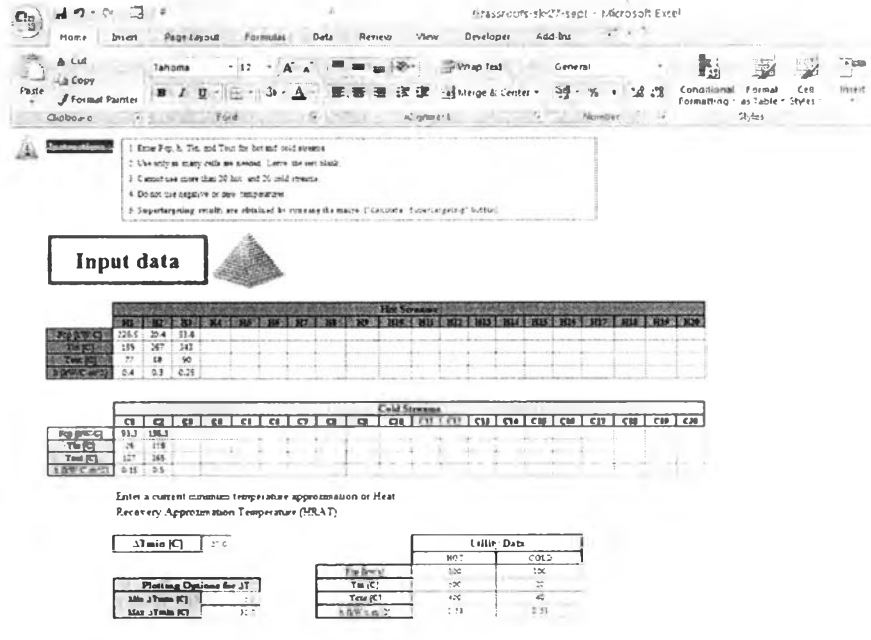



**Figure B1** MS office Program Feature.

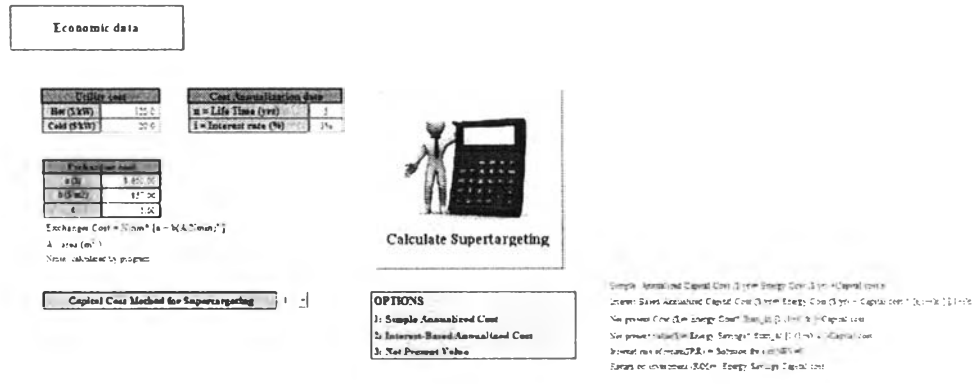



**Figure B1 (Cont.)** MS office Program Feature.

Warning:

- Enter Fcp, h, Tin, and Tout for hot and cold streams.
- Use only as many cells are needed. Leave the rest blank.
- Cannot use more than 20 hot and 20 cold streams.
- Do not use negative or zero temperatures.
- Supertargeting results are obtained by running the macro ("Calculate Supertargeting" button)

*B1.3 Instructions*

B1.3.1 Enter Fcp (kW/°C), h (kW/°C.m$^2$), Tin (°C), and Tout (°C) for hot and cold streams as shown in Figure 2B.

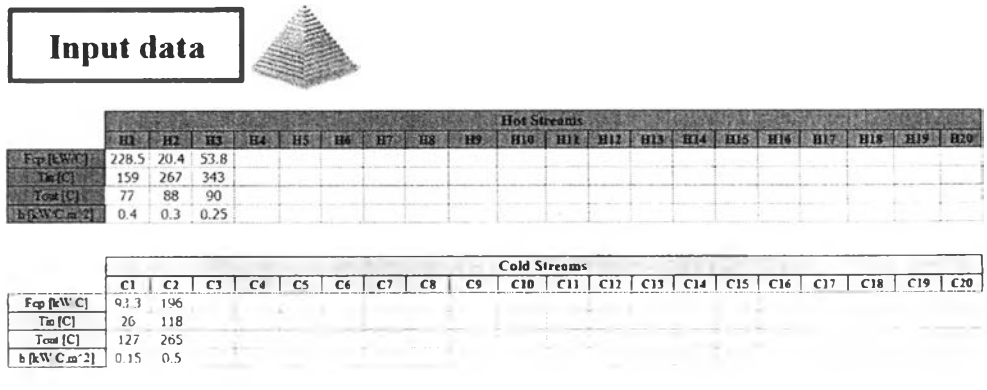
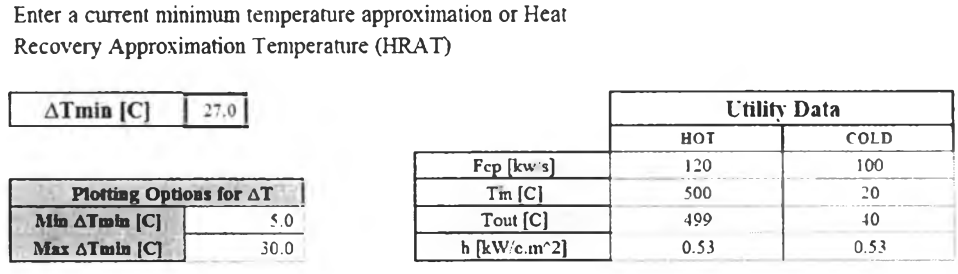



**Figure B2** Input Fcp, h, Tin, and Tout.

B1.3.2 Enter a current minimum temperature approximation or Heat Recovery Approximation Temperature (HRAT), HRAT region for calculation, and Utility Data as illustrated in Figure 3B.



Enter a current minimum temperature approximation or Heat Recovery Approximation Temperature (HRAT)

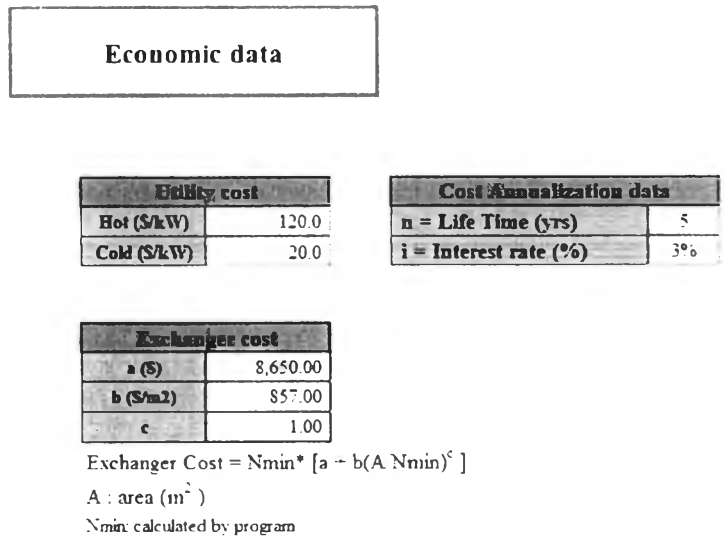
| ΔTmin [C] | 27.0 |
|---|---|

| Plotting Options for ΔT | |
|---|---|
| Min ΔTmin [C] | 5.0 |
| Max ΔTmin [C] | 30.0 |

| | Utility Data | |
|---|---|---|
| | HOT | COLD |
| Fcp [kw/s] | 120 | 100 |
| Tin [C] | 500 | 20 |
| Tout [C] | 499 | 40 |
| h [kW/c.m^2] | 0.53 | 0.53 |

**Figure B3** HRAT, HRAT region for calculation, and Utility Data.

B1.3.3 Enter an Economic Data which consisted of Utility cost, Cost annualized data, and Exchanger cost (Cost law coefficient). As illustrated in Figure 4B.



**Economic data**

| Utility cost | |
|---|---|
| Hot ($/kW) | 120.0 |
| Cold ($/kW) | 20.0 |

| Cost Annualization data | |
|---|---|
| n = Life Time (yrs) | 5 |
| i = Interest rate (%) | 3% |

| Exchanger cost | |
|---|---|
| a ($) | 8,650.00 |
| b ($/m2) | 857.00 |
| c | 1.00 |

Exchanger Cost = Nmin* [a + b(A/Nmin)$^c$ ]

A : area (m$^2$ )

Nmin: calculated by program

**Figure B4** Economic Data.

B1.3.4 Select an option for Capital Cost Method for Supertargeting which are

- Simple Annualized Cost

$$SimpleAnnualizedCost = EnergyCost + \frac{CapitalCost}{n}$$

- Interest Base Annualized Cost

$$InterestBaseAnnualizedCost = EnergyCost + CapitalCost \times \frac{i \times (i+i)^n}{(i+1)^n - 1}$$

- Net Present Value

$$NPV = EnergySaving \times \sum_{k=1}^{n} \frac{1}{(1+i)^k} - CapitalCost\ .$$

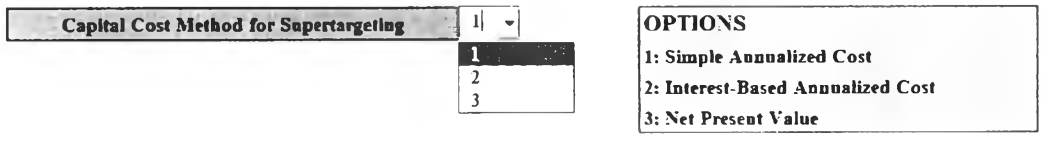



**Figure B5** Capital Cost Method for Supertargeting.

B1.3.5 Supertargeting results are obtained by running the macro ("Calculate Supertargeting" button)

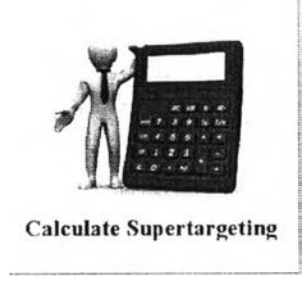



**Figure B6** Calculate Supertargeting Button.

*B1.4 Main results: The Program can automatically generate results as shown in Figure 7B.*

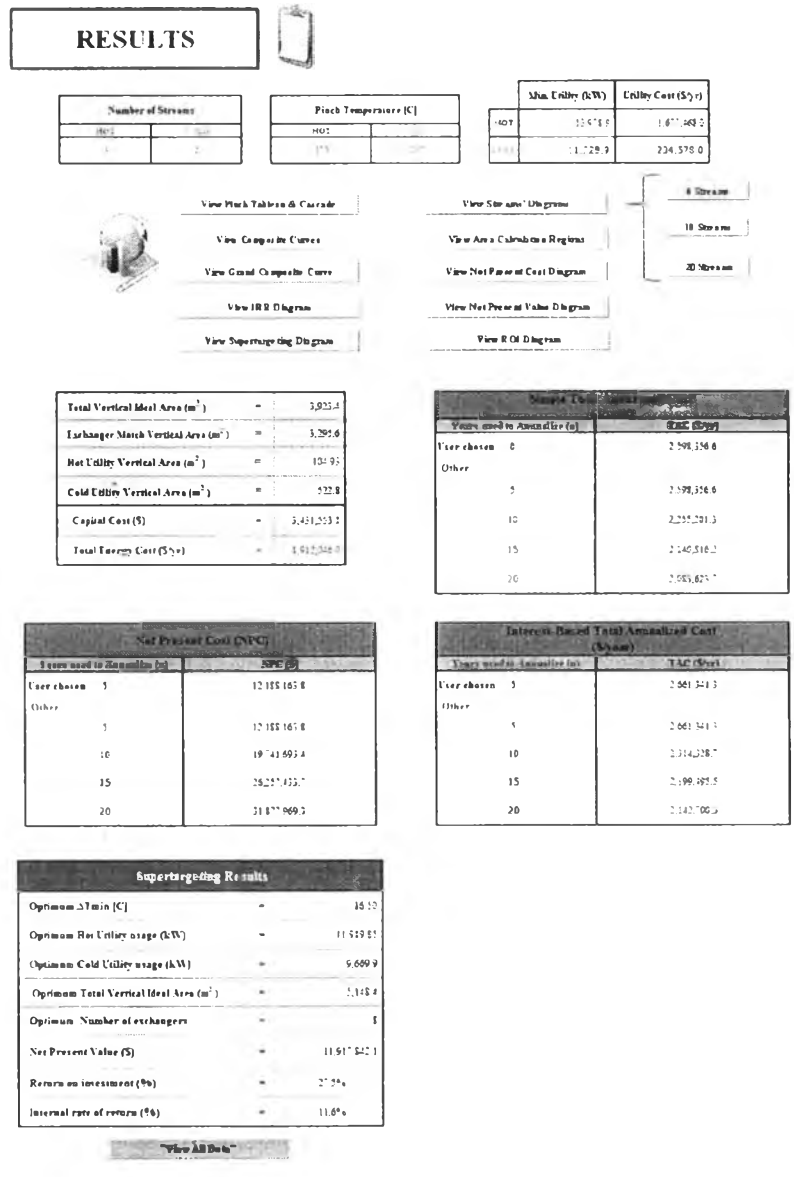



**Figure B7** Main Results Feature.

*B1.5 Number of streams, Pinch temperature, Minimum utility, and Utility cost are shown at the top of result as illustrated in Figure 8B.*

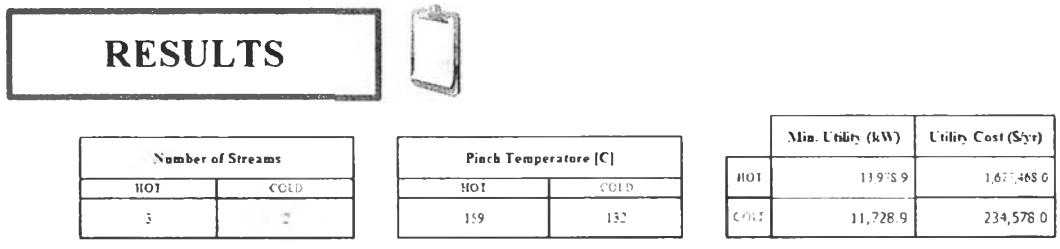



**Figure B8** Number of streams, Pinch temperature, Minimum utility, and Utility cost.

*B1.6 There are 13 command buttons; "View Pinch Tableau & Cascade", "View Composite Curves", "View Grand Composite Curve", "Streams' Diagrams", "6 Streams", "10 Streams", "20 Streams", "Area Calculation Regions", "Net Present Cost", "Net Present Value", "Internal rate of return", "Return on investment", and "Supertargeting diagram" which can automatically show those results*

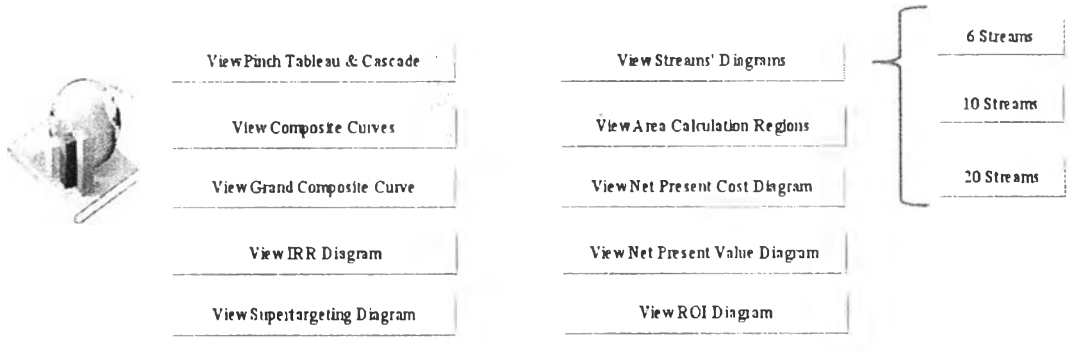



**Figure B9** All 13 command buttons.

*B1.7 Total vertical ideal area, Exchanger match vertical ideal area, Hot utility vertical ideal area, Cold utility vertical ideal area, Number of exchangers, Capital cost, and Energy cost are shown in the table as illustrated in Figure 10B.*

| | | |
|---|---|---|
| Total Vertical Ideal Area ($m^2$) | = | 3,923.4 |
| Exchanger Match Vertical Area ($m^2$) | = | 3,295.6 |
| Hot Utility Vertical Area ($m^2$) | = | 104.9 |
| Cold Utility Vertical Area ($m^2$) | = | 522.8 |
| Number of Exchangers | = | 8 |
| Total Energy Cost ($/yr) | = | 1,912,046.0 |
| Capital Cost ($) | = | 3,431,553.1 |

**Figure B10** Ideal area, Number of exchangers, Energy cost, and Capital cost table.

*B1.8 Simple total annualized cost, Interest-based total annualized cost, and Net present cost are shown in the table as shown in Figure 11B.*

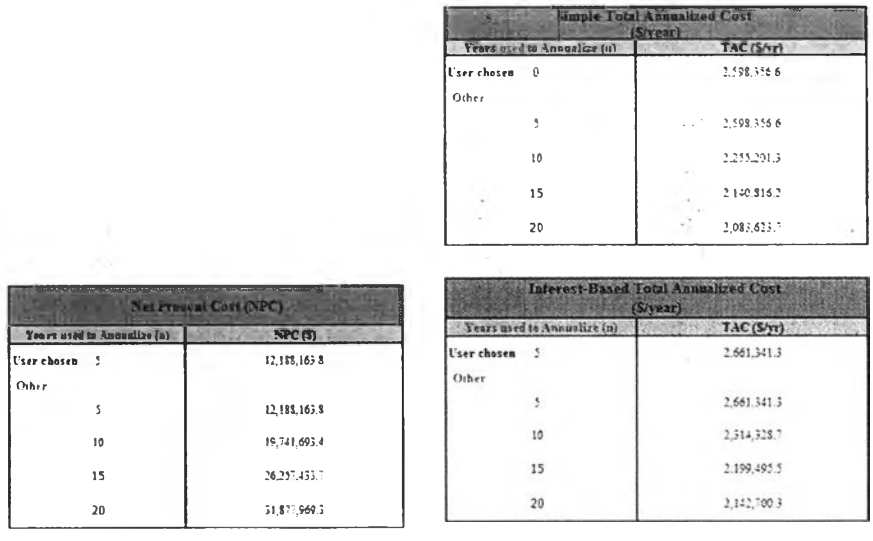



**Figure B11** Simple total annualized cost, Interest-based total annualized cost, and Net present cost.

*B1.9 Supertargeting results are shown in Figure 12B. View all data command button can automatically show all data in detail.*

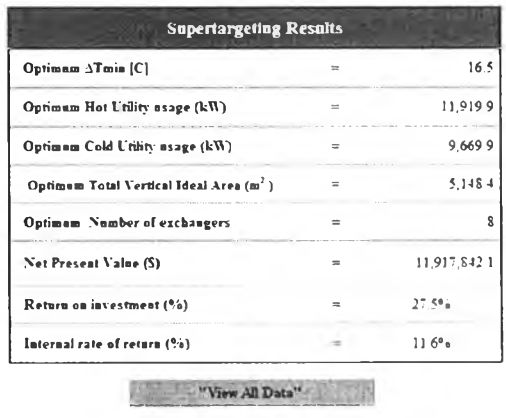



**Figure B12** Supertargeting results and View all data command button.

*B1.10 Printing option for Composite curves and Grand composite curve which is used for adjusting an axis scale as illustrated in Figure 13B. There are 2 options auto scale and adjust scale. Push update value button every time after selecting an option and input scale value.*

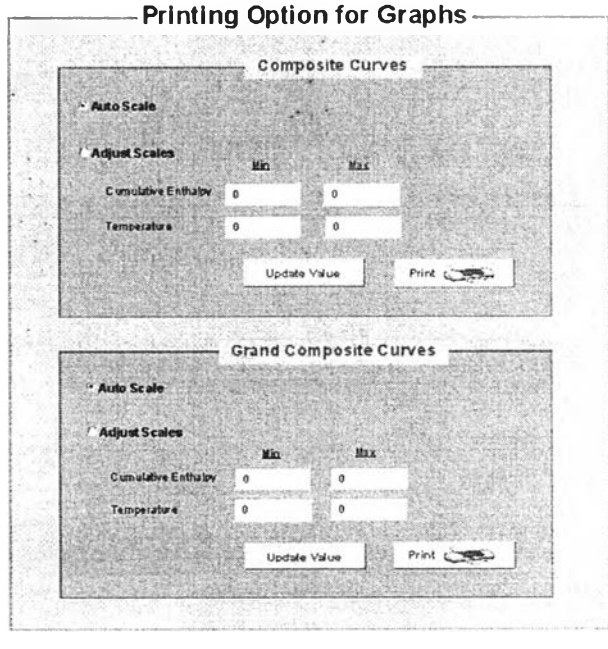



**Figure B13** Printing option for Composite Curves and Grand Composite Curve.

*B1.11 Worksheets*

B1.11.1 "INPUT DATA & MAIN RESULTS"

Sheet "INPUT DATA & MAIN RESULTS" is consist of 2 parts Input data and results as illustrated in Figure 1B, 7B.

B1.11.2 Tableau & Stream Cascade

Sheet "Tableau & Stream Cascade" shows problem table or pinch cascade and stream plot as shown in Figure 39. Automatically show when push "View Pinch Tableau & Stream Cascade" button in sheet "INPUT DATA & MAIN RESULTS".

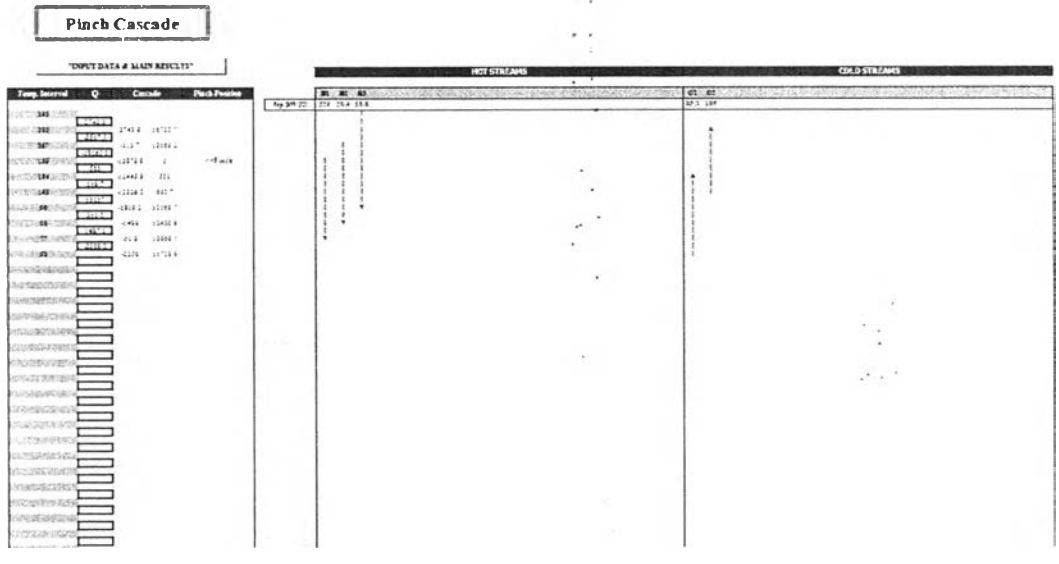



**Figure B14** Sheet "Tableau & Stream Cascade".

B1.11.3 Composite curves

Sheet "Composite curves" shows composite curves of input stream data which automatically show when push "View Composite Curves" button in sheet "INPUT DATA & MAIN RESULTS".

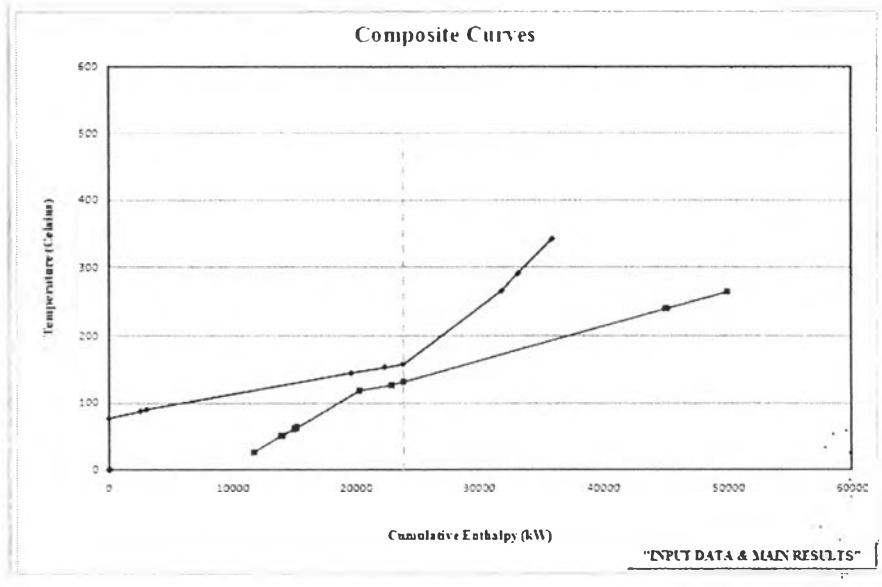



**Figure B15** Sheet "Composite Curves".

B1.11.4 Grand Composite

Sheet "Grand composite" show Grand composite curve of input stream data which automatically show when push "View Grand Composite Curve" button in sheet "INPUT DATA & MAIN RESULTS".

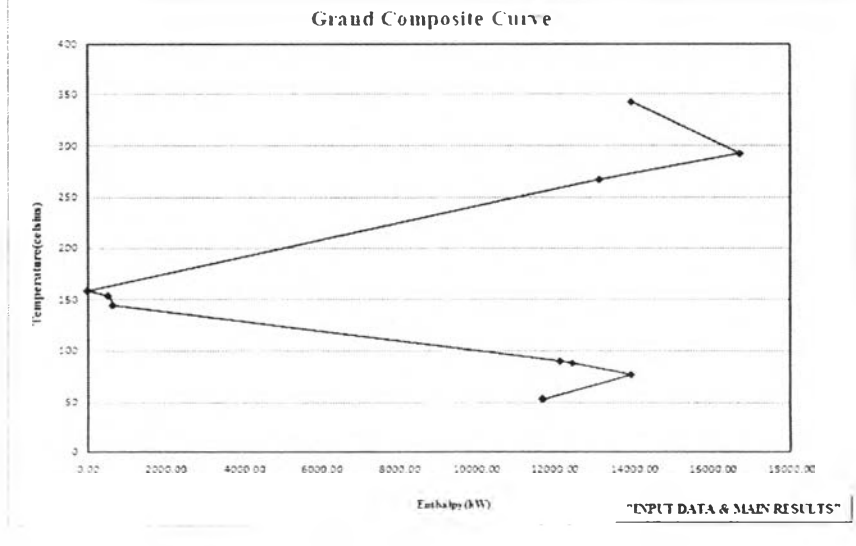



**Figure B16** Sheet "Grand Composite".

B1.11.5 Stream Diagram, 20 Streams, 10 Streams, and 6 Streams

Sheet "Stream Diagram", "20 Streams", "10 Stream", and "6 Steams" show 40 streams' diagram, 20 streams' diagram, 10 streams' diagram, and 6 streams' diagram, respectively of input stream data which automatically show when push "View Streams' Diagram", "20 streams' diagram", "10 streams' diagram", and "6 streams' diagram" button, respectively in sheet "INPUT DATA & MAIN RESULTS".

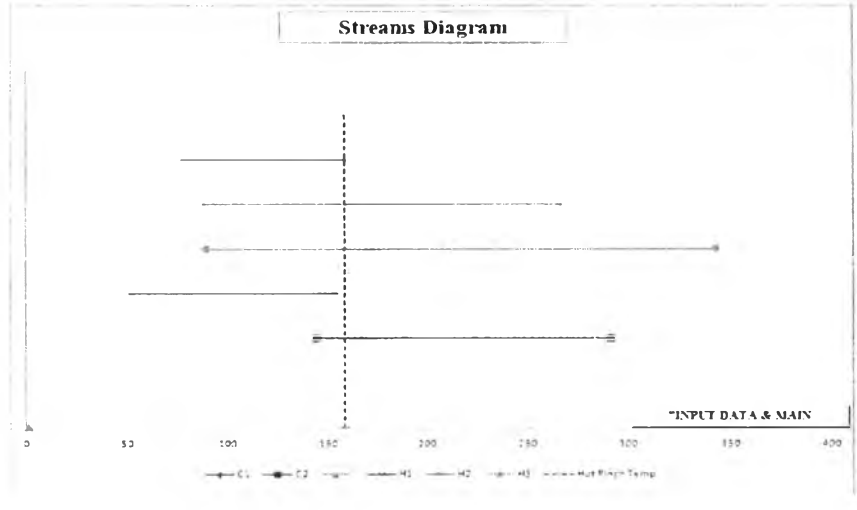



**Figure B17** Sheet "6 Streams".

B1.11.6 Area Calculation Region

Sheet "Area Calculation Region" shows Vertical heat transfer area calculation region of input stream data and utility data which automatically show when push "View Area Calculation Region" button in sheet "INPUT DATA & MAIN RESULTS".

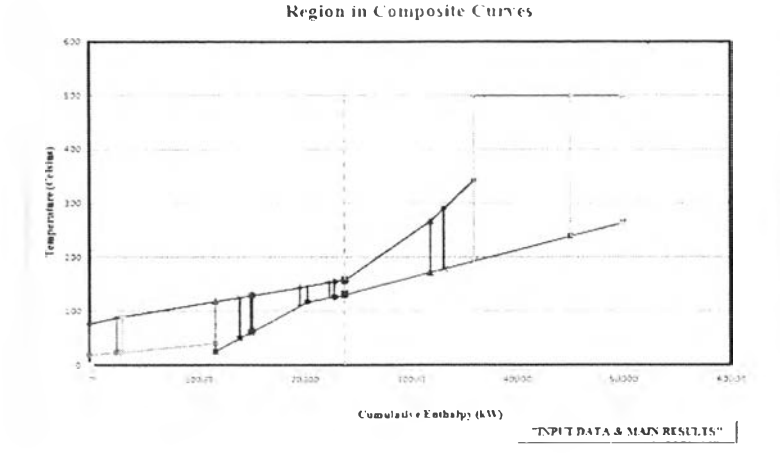



**Figure B18** Sheet "Area Calculation Region".

B1.11.7 Supertargeting

Sheet "Supertargeting" shows Economic Trade-off of selecting option and input stream data which automatically show when push "View Supertargeting Diagram" button in sheet "INPUT DATA & MAIN RESULTS".

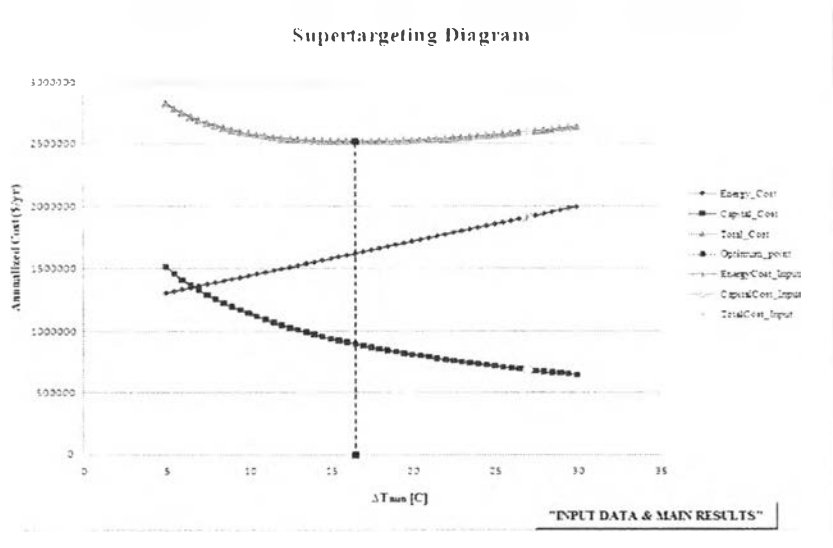



**Figure B19** Sheet "Supertargeting".

B1.11.8 IRR, NPC, NPV, ROI

Sheet "IRR", "NPC", "NPV", and "ROI" show Rate of Return, Net Present Cost, Net Present Value, and Return on investment, respectively which automatically show when push "View IRR Diagram", "View Net Present Cost", "View Net Present Value", and "View ROI Diagram" button, respectively in sheet "INPUT DATA & MAIN RESULTS".

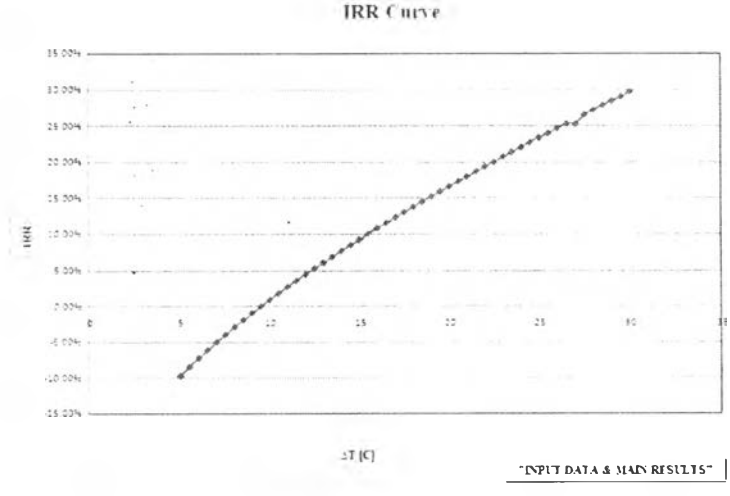



**Figure B20** Sheet "IRR".

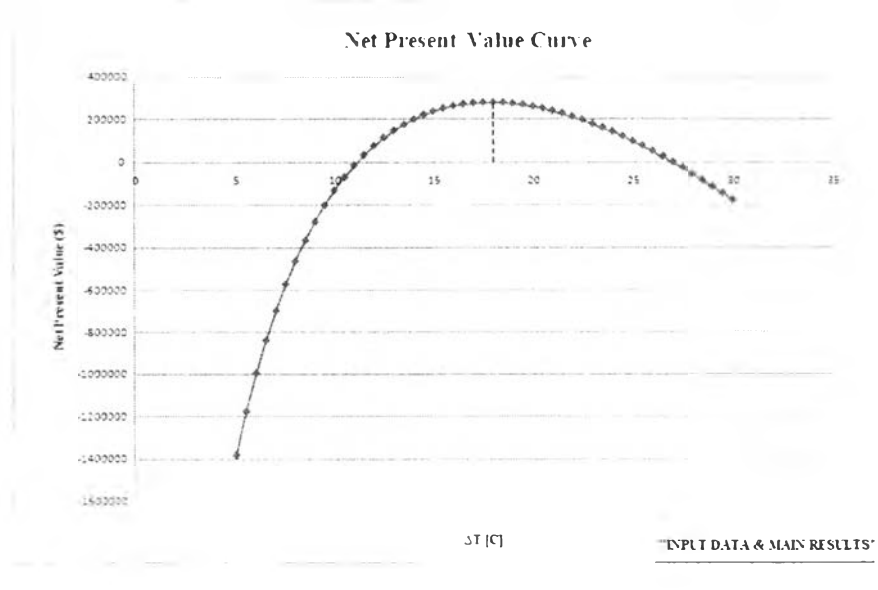



**Figure B21** Sheet "NPV".

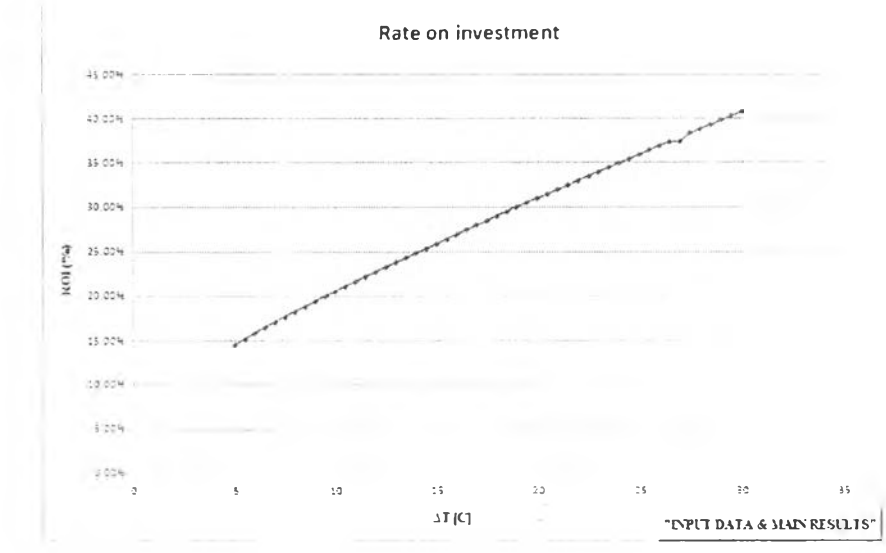


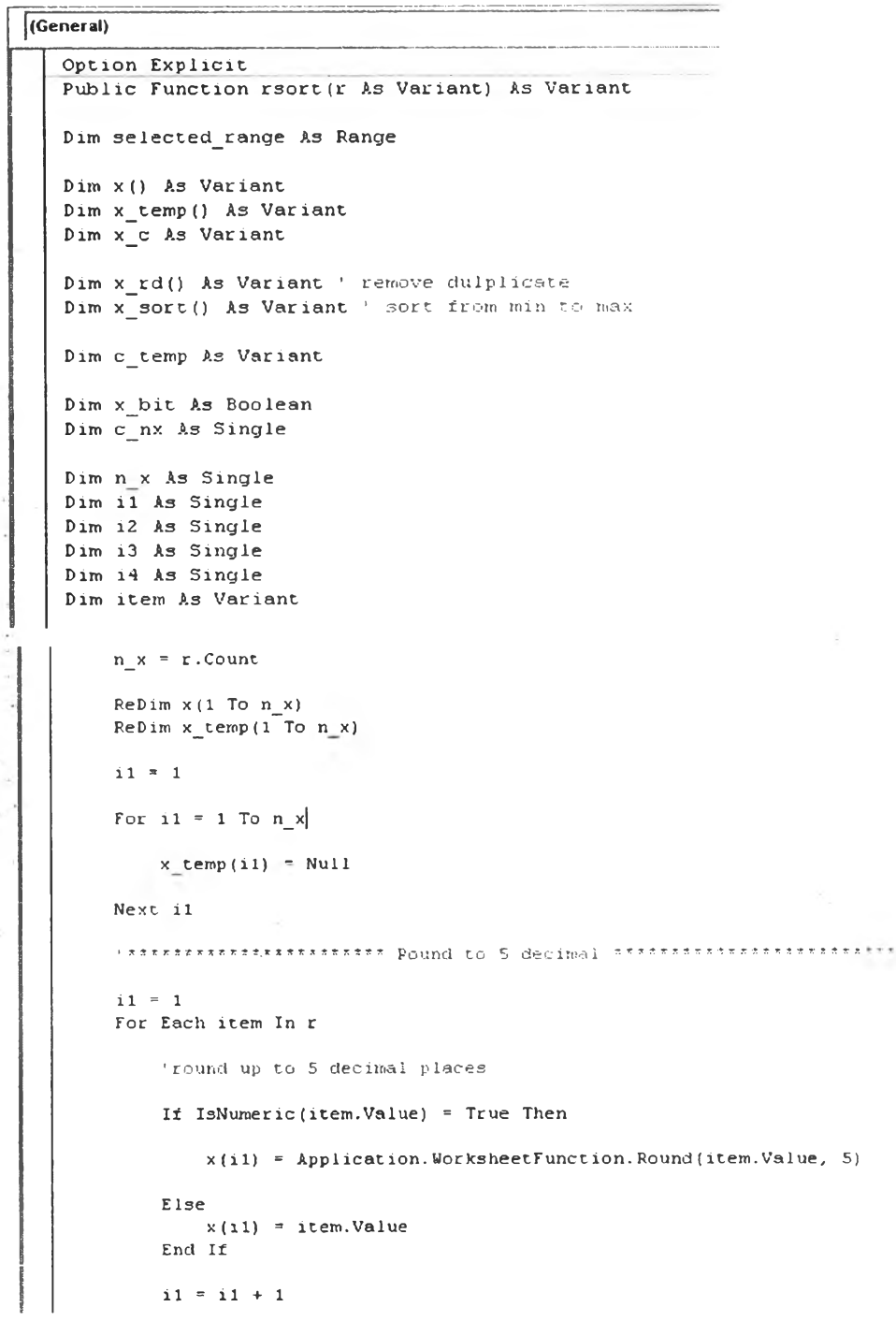

**Figure B22** Sheet "ROI".

B1.11.9 Aux-arrange temp, Aux-Cascade, Aux-Graphs, Aux-Aideal, and Supertargeting Calculation

Sheet "Aux-arrange temp", "Aux-Cascade", "Aux-Graphs", "Aux-Aideal", and "Supertargeting Calculation" is an auxiliary sheet which contain formula and functions for evaluation the results.

*B1.12 Visual Basic for Application (Source code)*

B1.12.1 Sort Data Function (in Module 4)



```
(General)

Option Explicit
Public Function rsort(r As Variant) As Variant

Dim selected_range As Range

Dim x() As Variant
Dim x_temp() As Variant
Dim x_c As Variant

Dim x_rd() As Variant ' remove dulplicate
Dim x_sort() As Variant ' sort from min to max

Dim c_temp As Variant

Dim x_bit As Boolean
Dim c_nx As Single

Dim n_x As Single
Dim i1 As Single
Dim i2 As Single
Dim i3 As Single
Dim i4 As Single
Dim item As Variant

    n_x = r.Count

    ReDim x(1 To n_x)
    ReDim x_temp(1 To n_x)

    i1 = 1

    For i1 = 1 To n_x

        x_temp(i1) = Null

    Next i1

    '********************** Round to 5 decimal **********************

    i1 = 1
    For Each item In r

        'round up to 5 decimal places

        If IsNumeric(item.Value) = True Then

            x(i1) = Application.WorksheetFunction.Round(item.Value, 5)

        Else
            x(i1) = item.Value
        End If

        i1 = i1 + 1
```

**Figure B23** Sort Data Function (in Module 4).

```
    Next

    '********************** Remove Duplicate Data ************************

    i1 = 1
    c_nx = 1

    For i1 = 1 To n_x

        x_c = x(i1)

        If Not IsNumeric(x_c) = True Then

            GoTo next_x

        End If

            For i2 = 1 To n_x

               If x_c = x_temp(i2) Then

                    x_bit = True

               End If

            Next i2

            If x_bit = False Then
                x_temp(c_nx) = x_c

                c_nx = c_nx + 1
            End If


    x_bit = False

next_x:

    Next i1
    '********************** Collect Data in Array ************************
    Dim n_r As Single

    n_r = c_nx - 1

    ReDim x_rd(1 To n_r)

    i1 = 1

    For i1 = 1 To n_r

        x_rd(i1) = x_temp(i1)

    Next i1


    '********************** Sort data from min to max ********************

    ReDim x_sort(1 To n_r)

    i1 = 1

    For i1 = 1 To n_r

        x_sort(i1) = Application.WorksheetFunction.Small(x_rd, i1)

    Next i1

    i1 = 1
    '************************ Transpose Data *****************************

    rsort = Application.Transpose(x_sort)

End Function
```

**Figure B23 (Cont.)** Sort Data Function (in Module 4).

## B1.12.2 Discount Factor Function (in Module 5)

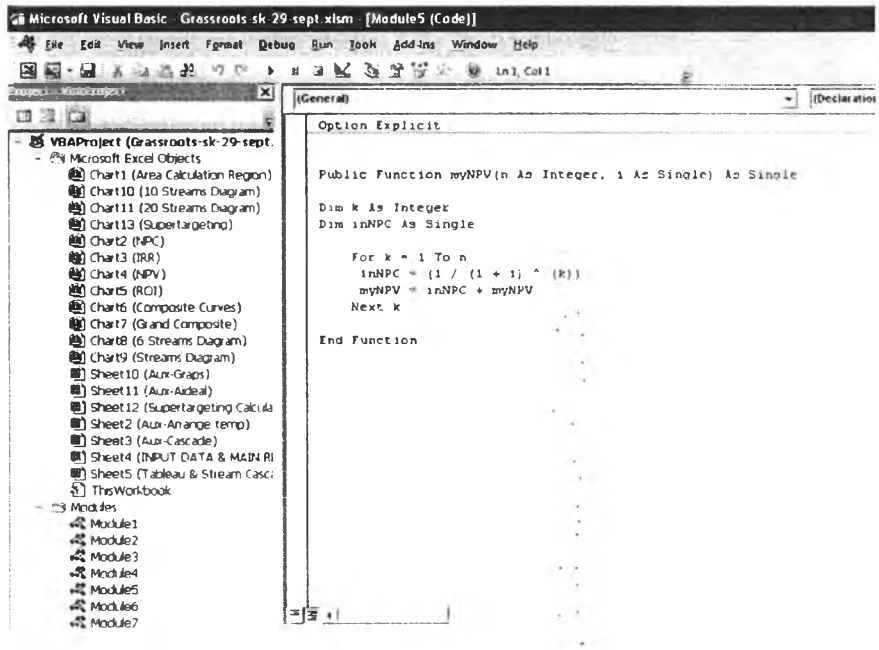



**Figure B24** Discount factor function (in Module 5).

## 1.12.3B Vary DTmin procedure (in Module 7)

```
Option Explicit
Sub Supertargeting()

'---------- To collect Hot & Cold Utility of base case ----------

   Sheets("Aux-Cascade").Select
   Range("C18").Select
   Selection.Copy

   Sheets("Aux-Aideal").Select
   Range("BR19").Select
   Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
      :=False, Transpose:=False

   Sheets("Aux-Cascade").Select
   Range("C20").Select
```

```
    Application.CutCopyMode = False

    Selection.Copy
    Sheets("Aux-Aideal").Select
    Range("BR20").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False

    Sheets("Aux-Cascade").Select
    Application.CutCopyMode = False

'------------ To collect capitalcost of base case ----------

    Sheets("Aux-Aideal").Select
    Range("BS14").Select
    Selection.Copy
    Range("BS13").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Application.CutCopyMode = False



'------------------ To vary delta T 50 times ------------------


'*************************************************************]

    Sheets("INPUT DATA & MAIN RESULTS").Select
    Range("F34").Select
    Selection.Copy

    Range("AH53").Select
    ActiveSheet.Paste
    Application.CutCopyMode = False

    Range("F34").Select
```

```
ActiveCell.FormulaR1C1 = "=R[-32]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C11").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'**************************************************************2

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-31]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C12").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'**************************************************************3

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-30]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
```

```
Sheets("Supertargeting Calculations").Select
Range("C13").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*************************************************************4

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-29]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C14").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*************************************************************5

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-28]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C15").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*************************************************************6
```

```
Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-27]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C16").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*****************************************************************7

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-26]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C17").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*****************************************************************8

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-25]C[28]"
```

```
Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C18").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*************************************************************9

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-24]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C19").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*************************************************************10

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-23]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C20").Select
```

```
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*****************************************************************11

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-22]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C21").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

'*****************************************************************12

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-21]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C22").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
```

```
'*****************************************************************13

    Sheets("INPUT DATA & MAIN RESULTS").Select
    Range("F34").Select

    ActiveCell.FormulaR1C1 = "=R[-20]C[28]"


    Sheets("Aux-Aideal").Select
    Range("ca15:ct15").Select
    Selection.Copy
    Sheets("Supertargeting Calculations").Select
    Range("C23").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False


    '*****************************************************************14

    Sheets("INPUT DATA & MAIN RESULTS").Select
    Range("F34").Select

    ActiveCell.FormulaR1C1 = "=R[-19]C[28]"


    Sheets("Aux-Aideal").Select
    Range("ca15:ct15").Select
    Selection.Copy
    Sheets("Supertargeting Calculations").Select
    Range("C24").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False


    '*****************************************************************15

    Sheets("INPUT DATA & MAIN RESULTS").Select
```

```
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-18]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C25").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************16

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-17]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C26").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************17

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-16]C[28]"
```

```
Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C27").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
   :=False, Transpose:=False

'*************************************************************18

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-15]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C28").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
   :=False, Transpose:=False


'*************************************************************19

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-14]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
```

```
Sheets("Supertargeting Calculations").Select
Range("C29").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False




'*************************************************************20

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-13]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C30").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************21

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-12]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
```

```
Range("C31").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************22

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-11]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C32").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************23

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-10]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C33").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
```

```
'*****************************************************************24

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-9]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C34").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*****************************************************************25

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-8]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C35").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*****************************************************************26

Sheets("INPUT DATA & MAIN RESULTS").Select
```

```
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-7]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C36").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False




'*************************************************************27

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-6]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C37").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************28

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select
```

```
ActiveCell.FormulaR1C1 = "=R[-5]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C38").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************29

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-4]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C39").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************30

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-3]C[28]"


Sheets("Aux-Aideal").Select
```

```
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C40").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************31

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-2]C[28]"



Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C41").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************32

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[-1]C[28]"



Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C42").Select
```

```
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************33

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[0]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C43").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************34

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[1]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C44").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
```

```
'*****************************************************************35

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[2]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C45").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*****************************************************************36

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[3]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C46").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*****************************************************************37

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select
```

```
ActiveCell.FormulaR1C1 = "=R[4]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C47").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************38

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[5]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C48").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************39

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[6]C[28]"
```

```
Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C49").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************40

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[7]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C50").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************41

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[8]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
```

```
Range("C51").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************42

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[9]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C52").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False



'*************************************************************43

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[10]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C53").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
```

```
   :=False, Transpose:=False

'*****************************************************************44

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[11]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C54").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
   :=False, Transpose:=False


'*****************************************************************45

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[12]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C55").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
   :=False, Transpose:=False


'*****************************************************************46
```

```
Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[13]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C56").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************47

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[14]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C57").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************48

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select
```

```
ActiveCell.FormulaR1C1 = "=R[15]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C58").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************49

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[16]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C59").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*************************************************************50

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select
```

```
ActiveCell.FormulaR1C1 = "=R[17]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C60").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'*****************************************************************51

Sheets("INPUT DATA & MAIN RESULTS").Select
Range("F34").Select

ActiveCell.FormulaR1C1 = "=R[18]C[28]"


Sheets("Aux-Aideal").Select
Range("ca15:ct15").Select
Selection.Copy
Sheets("Supertargeting Calculations").Select
Range("C61").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False


'******************** INPUT Delta T**********************

Sheets("INPUT DATA & MAIN RESULTS").Select

Range("AH53").Select
Selection.Copy
Range("F34").Select
ActiveSheet.Paste
Application.CutCopyMode = False
```

```
    Sheets("Aux-Aideal").Select
    Range("ca15:ct15").Select
    Selection.Copy
    Sheets("Supertargeting Calculations").Select
    Range("C66").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False


    Sheets("Aux-Aideal").Select
    Application.CutCopyMode = False


    Sheets("INPUT DATA & MAIN RESULTS").Select
    ActiveWindow.ScrollWorkbookTabs Position:=xlFirst
End Sub
```

## B2 Potential Retrofit Program

### *B2.1 Background*

Heat exchanger network (HEN) design is a key aspect of chemical process design. Previous research work (Linnhoff and Hinmarsh, 1983; Floudas et al., 1986; Yee and Grossmann, 1990) has mainly been directed to develop methods for the grassroots design of HEN's. However, during the past two decades, the retrofit of existing HEN has become more important than grassroots design. Because it gives a higher practical designed HEN in order to reduce significantly the operating costs.

Retrofit methods can be grouped into three broad categories which are thermodynamic based approaches including pinch analysis, mathematical programming methods and approaches combining both (Rezaei and Shafiei, 2009). The major objectives of retrofit problems are the reduction of the utility consumption, the full utilization of the existing exchangers and identification of the required structural modifications.

Retrofit mechanisms:

- Addition of one or more new heat exchangers (in series or parallel)
- Relocation of existing exchangers
- Area addition to existing heat exchangers
  - Adding a shell
  - Exchanging the bank of tubes by one more efficient (Brown Fintube, Houston, TX)
- Area reduction to existing heat exchangers
- Modify piping on one or both sides of the heat exchangers

*B2.2 MS office incorporated with Visual Basic for Application (VBA) Program*

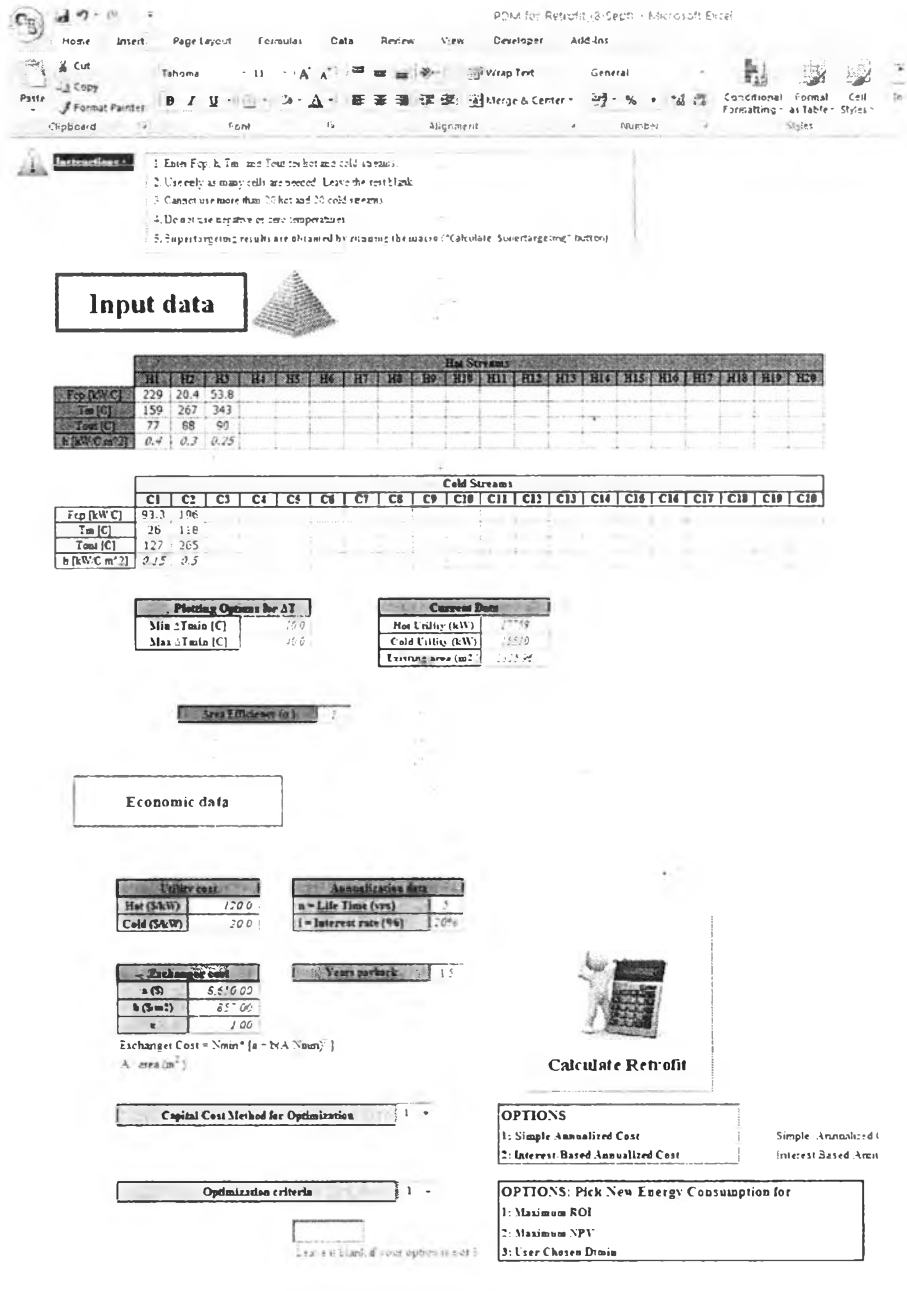



**Figure B25** MS office Program Feature.

*B2.3 Instructions*

B2.3.1 Enter Fcp (kW/°C), h (kW/°C.m$^2$), Tin (°C), and Tout (°C) for hot and cold streams as shown in Figure 26B.

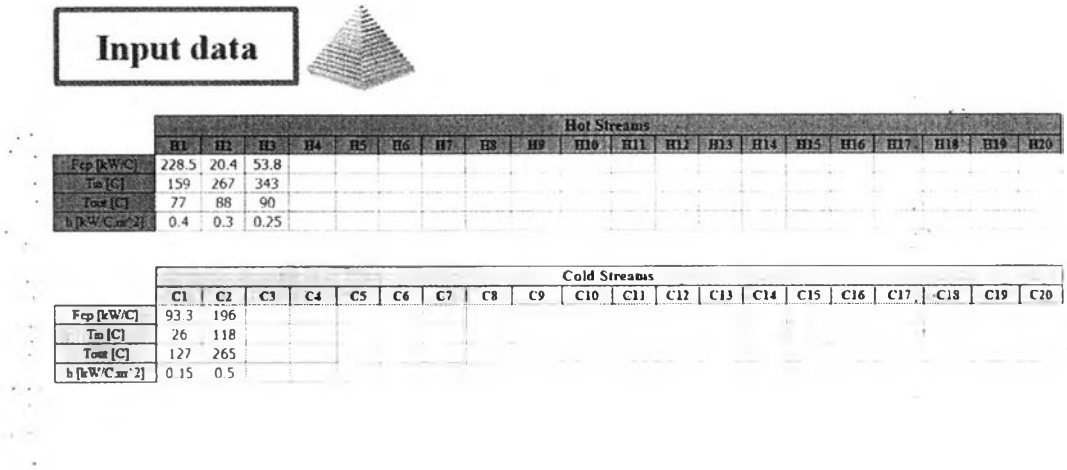



**Figure B26** Input Fcp, Tin, Tout, and h.

B2.3.2 Enter plotting options for ΔTmin, Current Data, and Area efficiency (α) as illustrated in Figure 53.

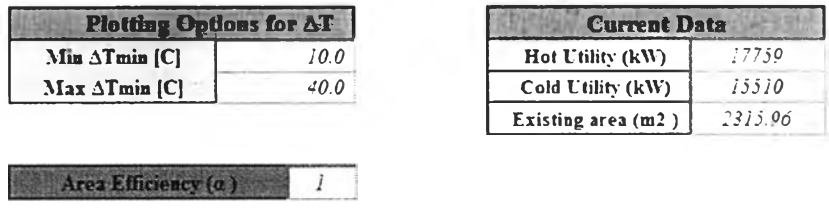



**Figure B27** Plotting options for ΔTmin, Current data, and Area efficiency.

B2.3.3 Enter an Economic Data which consisted of Utility cost, Cost annualized data, Exchanger cost (cost law coefficient), and Years payback.

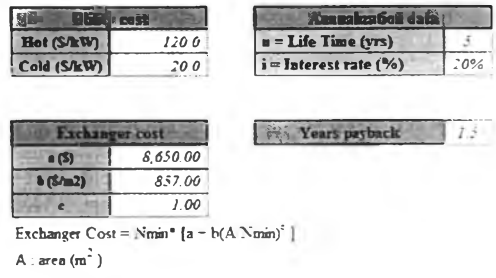



**Figure B28** Economic data.

B2.3.4 Select an option for Capital Cost Method for Supertargeting which are

- Simple Annualized Cost

$$SimpleAnnualizedCost = EnergyCost + \frac{CapitalCost}{n}$$

- Interest Base Annualized Cost

$$InterestBaseAnnualizedCost = EnergyCost + CapitalCost \times \frac{i \times (i+i)^n}{(i+1)^n - 1}$$


**Figure B29** Option for Capital cost method for supertargeting.

B2.3.5 Select an option for the optimum HEN

- Maximum ROI

ROI = Energy saving/Total investment

- Maximum NPV

$$NPV = [Energy\_saving \times \sum_{i=1}^{k} \frac{1}{(1+i)^k}] - Total\_investment$$

- User Chosen $DT_{min}$

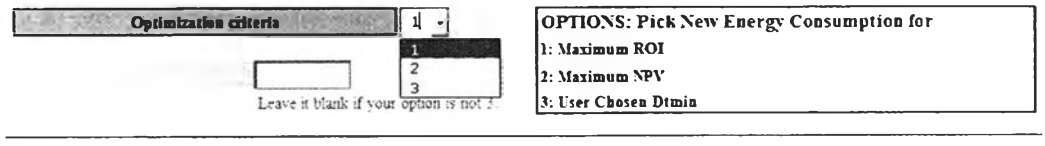



**Figure B30** Options for the optimum HEN.

B2.3.6 Supertargeting results are obtained by running the macro ("Calculate Supertargeting" button)

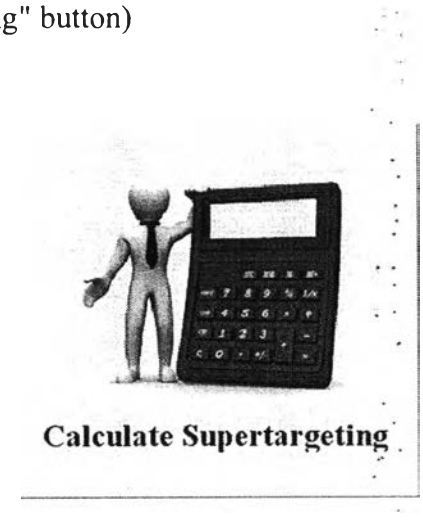



**Figure B31** Calculate Supertargeting Button.

*B2.4 Main results: The Program can automatically generate results as shown in Figure 32B.*

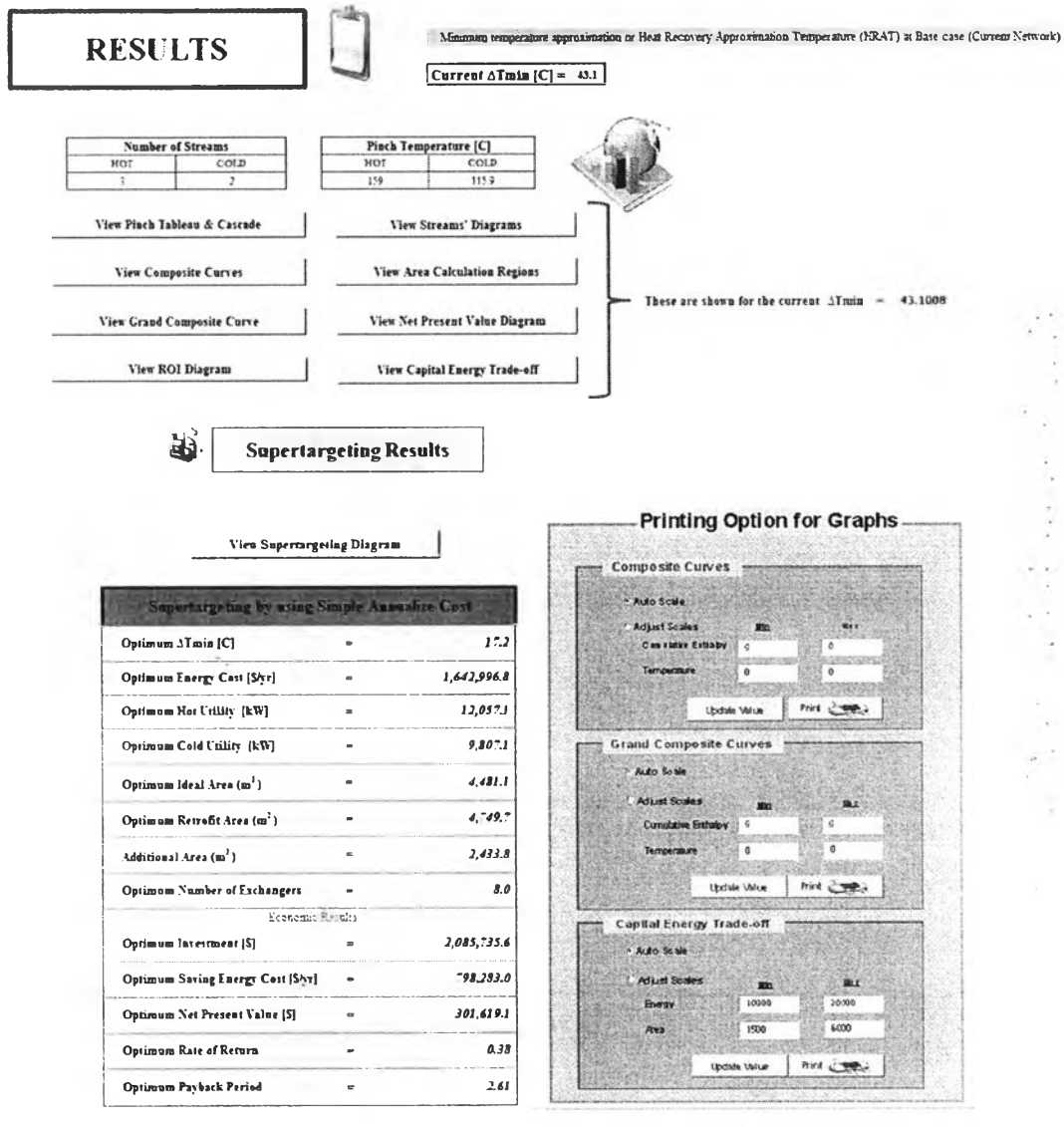



**Figure B32** Main Results Feature.

B2.4.1 Number of streams, Pinch temperature, and Current $\Delta T_{min}$ are shown at the top of result as illustrated in Figure 33B.

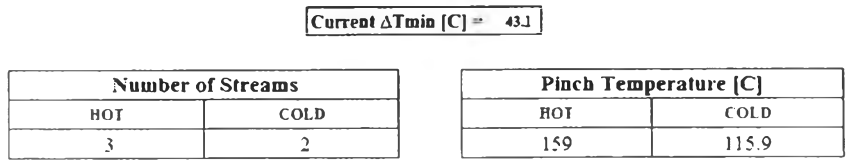



**Figure B33** Number of streams, Pinch temperature, and Current $\Delta T_{min}$.

B2.4.2 There are 8 command buttons; "View Pinch Tableau & Cascade", "View Composite Curves", "View Grand Composite Curve", "View Streams' Diagrams", "View Area Calculation Regions", "View Net Present Value Diagram", "View Capital Energy Trade-off", "View Return on investment diagram" which can automatically show those results when clicked.

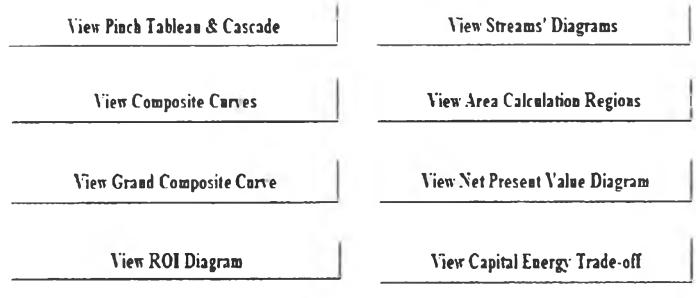



**Figure B34** Command buttons.

B2.4.3 Retrofit results

Supertargeting results with an option selected are shown in the table as illustrated in Figure 35B.

| Supertargeting by using Simple Annualize Cost | | |
|---|---|---|
| Optimum ΔTmin [C] | = | 17.2 |
| Optimum Energy Cost [$/yr] | = | 1,642,996.8 |
| Optimum Hot Utility [kW] | = | 12,057.1 |
| Optimum Cold Utility [kW] | = | 9,807.1 |
| Optimum Ideal Area ($m^2$) | = | 4,481.1 |
| Optimum Retrofit Area ($m^2$) | = | 4,749.7 |
| Additional Area ($m^2$) | = | 2,433.8 |
| Optimum Number of Exchangers | = | 8.0 |
| Economic Results | | |
| Optimum Investment [$] | = | 2,085,735.6 |
| Optimum Saving Energy Cost [$/yr] | = | 798,283.0 |
| Optimum Net Present Value [$] | = | 301,619.1 |
| Optimum Rate of Return | = | 0.38 |
| Optimum Payback Period | = | 2.61 |

**Figure B35** Supertargeting Results by selected an option.

B2.4.4 Printing option for Composite curves, Grand composite curve and Capital-Energy Trade-off which is used for adjusting an axis scale as illustrated in Figure 36B. There are 2 options auto scale and adjust scale. Push update value button every time after selecting an option and input scale value.

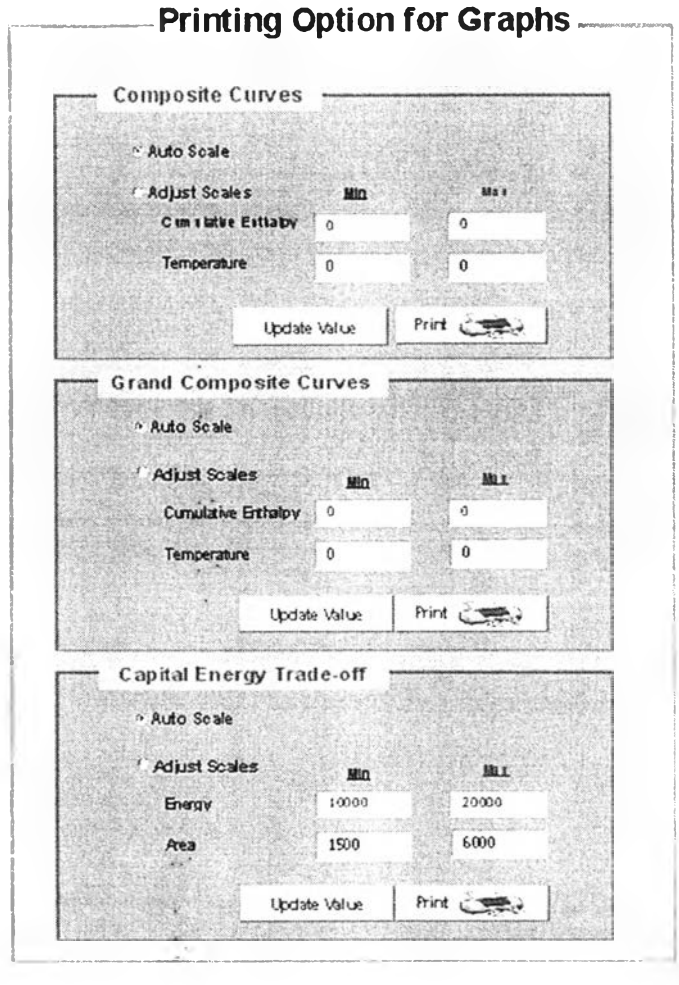



**Figure B36** Printing option for graphs.

B2.5 Worksheets

B2.5.1 "INPUT DATA & MAIN RESULTS"

Sheet "INPUT DATA & MAIN RESULTS" is consist of 2 parts Input data and results as illustrated in Figure 25B, 32B.

B2.5.2 Tableau & Stream Cascade

Sheet "Tableau & Stream Cascade" shows problem table or pinch cascade and stream plot as shown in Figure 14B. Automatically show when push "View Pinch Tableau & Stream Cascade" button in sheet "INPUT DATA & MAIN RESULTS".

B2.5.3 Composite curves

Sheet "Composite curves" shows composite curves of input stream data which automatically show when push "View Composite Curves" button in sheet "INPUT DATA & MAIN RESULTS". As illustrated in Figure 15B.

B2.5.4 Grand Composite

Sheet "Grand composite" show Grand composite curve of input stream data which automatically show when push "View Grand Composite Curve" button in sheet "INPUT DATA & MAIN RESULTS". As shown in Figure 16B.

B2.5.5 Stream Diagram, 20 Streams, 10 Streams, and 6 Streams

Sheet "Stream Diagram", show 40 streams' diagram of input stream data which automatically show when push "View Streams Diagram" button, in sheet "INPUT DATA & MAIN RESULTS". As illustrated in Figure 17B.

B2.5.6 Area Calculation Region

Sheet "Area Calculation Region" shows Vertical heat transfer area calculation region of input stream data which automatically show when push "View Area Calculation Region" button in sheet "INPUT DATA & MAIN RESULTS". As shown in Figure 18B.

B2.5.7 Supertargeting

Sheet "Supertargeting" shows Economic Trade-off of selecting option and input stream data which automatically show when push "View Supertargeting Diagram" button in sheet "INPUT DATA & MAIN RESULTS".

B2.5.8 NPV, ROI

Sheet "NPV" and "ROI" show Net Present Value and Return on investment, respectively which automatically show when push "View Net Present Value", "View ROI Diagram" button, respectively in sheet "INPUT DATA & MAIN RESULTS".

B2.5.9 Capital Energy Trade-off

Sheet "Capital Energy Trade-off" show the retrofit areas-energy curve from the selected area efficient ($\alpha$) which automatically show when push "View Capital Energy Trade-off" button in sheet "INPUT DATA & MAIN RESULTS".

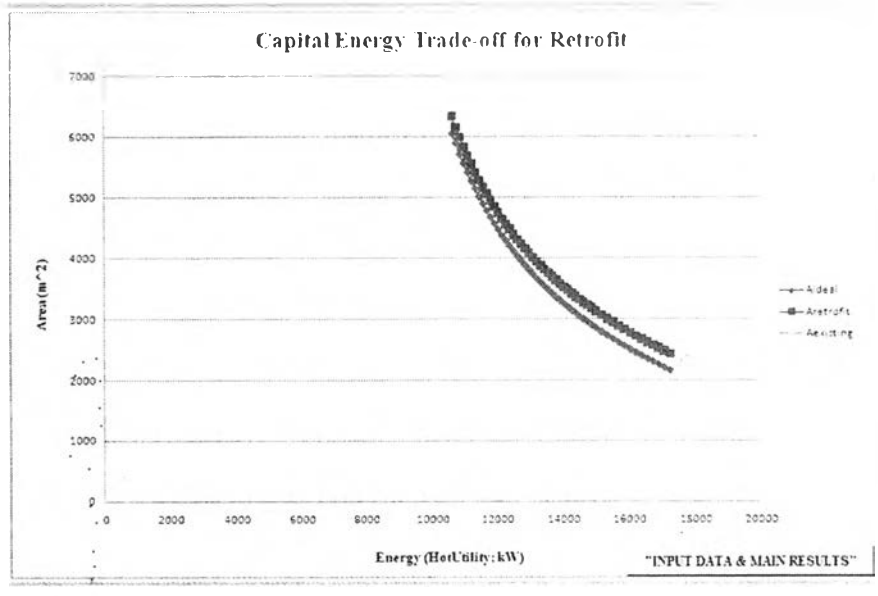



**Figure B37** Capital Energy Trade-off Diagram.

B2.5.10 Payback curve

Sheet "Payback curve" shows payback diagram of input stream data at 1, 2, 3, and selected year payback which automatically show when push "View Payback Diagram" button in sheet "INPUT DATA & MAIN RESULTS"

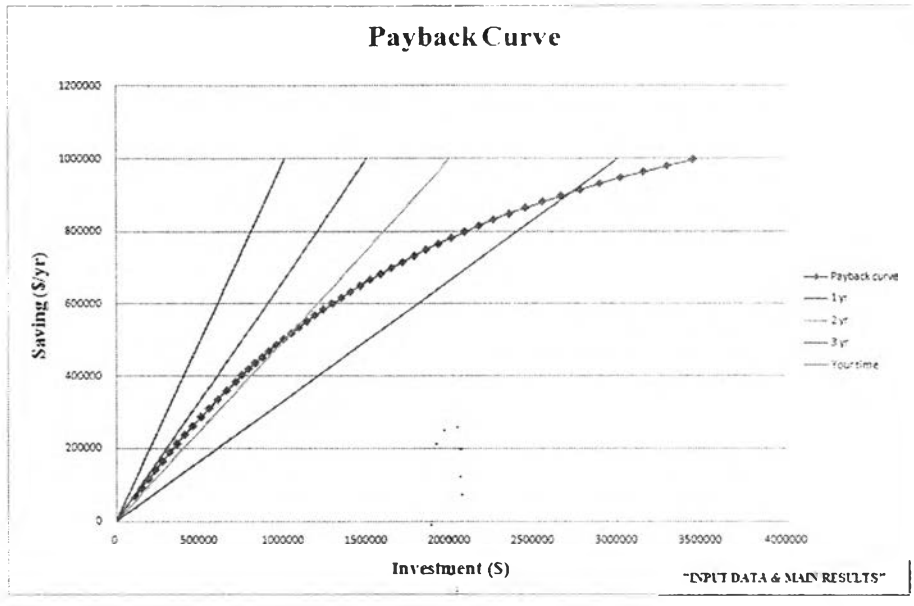



**Figure B38** Payback Diagram.

B2.6 Visual Basic for Application (Source code)

B2.6.1 Sort Data Function (in Module 4)

As shown in Figure 24B

B2.6.2 Discount Factor Function (in Module 5)

As shown in Figure 25B

B2.6.3 Vary DTmin procedure (in Module 7)

Source code is covered in more detail in section

# CURRICULUM VITAE

**Name:** Supachai Kosol

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**Educational Background:**

2005 – 2009 (GPA: 3.65) B.Eng with 1st class honour
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Senior Project: A Study Properties of PC/ABS blends.

2002 – 2005 (GPA: 3.94) Bodindecha (Sing Singhaseni) School,
(Grade 12) - Major Field of Mathematic-Science

**Extra-Curricular Activities:**

2010 (April) Staff in "The 1st National Research Symposium on Petroleum, Petrochemicals, and Advanced Materials" and "The 16th PPC Symposium on Petroleum, Petrochemicals, and Polymers" April 22, 2010 at Montien Hotel, Bangkok

2009 – Present Student President of Petroleum technology, The Petroleum and Petrochemical College, Chulalongkorn University

2006 – 2007 (December-February) Representative for teaching in General Chemistry 2 for 1st year students of Petrochemicals and Polymeric Materials, Silpakorn University

2005 – 2009 Deputy student president of Petrochemicals and Polymeric Materials, Silpakorn University