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APPENDICES

Appendix A Graphs from CMG Results

The following graphs that were generated from CMG Result are the relationship between recovery factor and pore volumes.

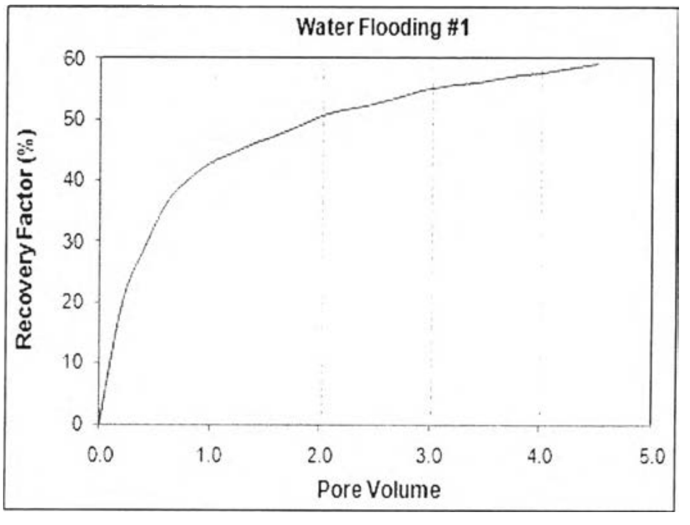

Figure A1 The simulation result of waterfloodingwith high permeability sand pack of 41.5 darcy and low oil viscosity of 440 cp.

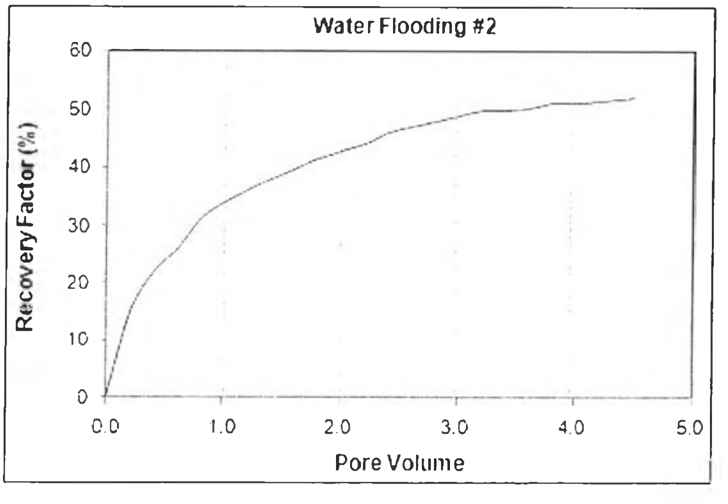

Figure A2 The simulation result of waterflooding with high permeability sand pack of 38.6 darcy and high oil viscosity of 1500 cp.

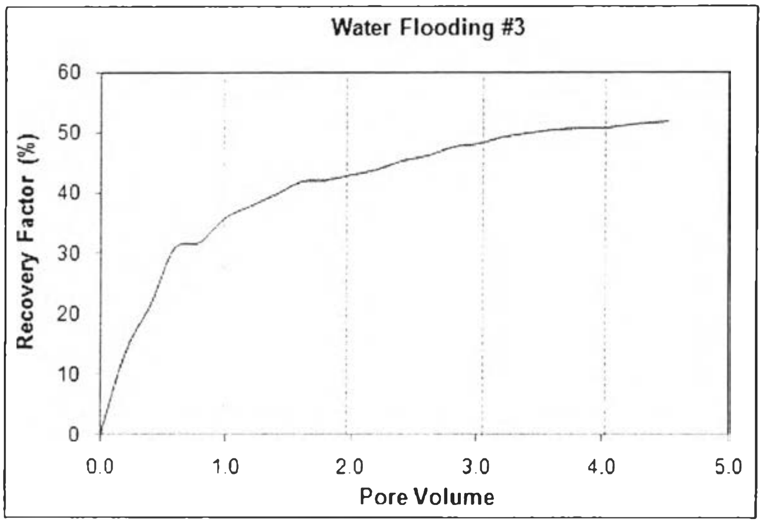

Figure A3 The simulation result of waterflooding with high permeability sand pack of 11.4 darcy and high oil viscosity of 1500 cp.

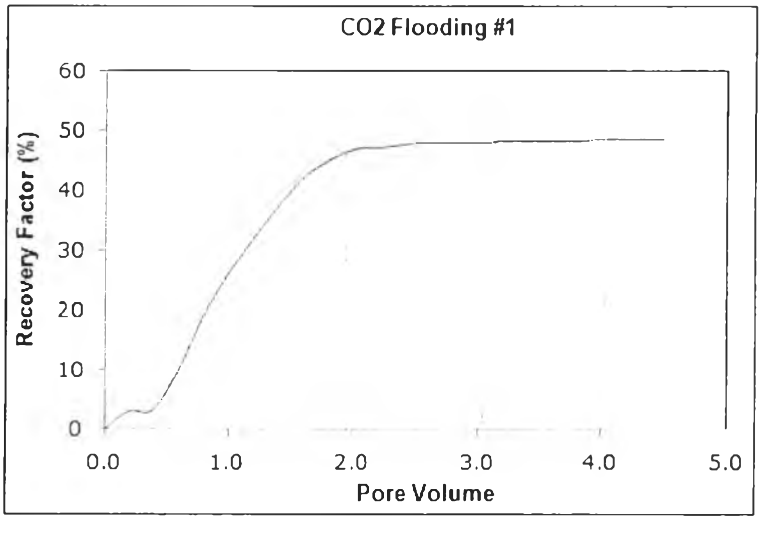

Figure A4 The simulation result of carbon dioxide flooding with high permeability sand pack of 41.5 darcy and low oil viscosity of 440 cp.

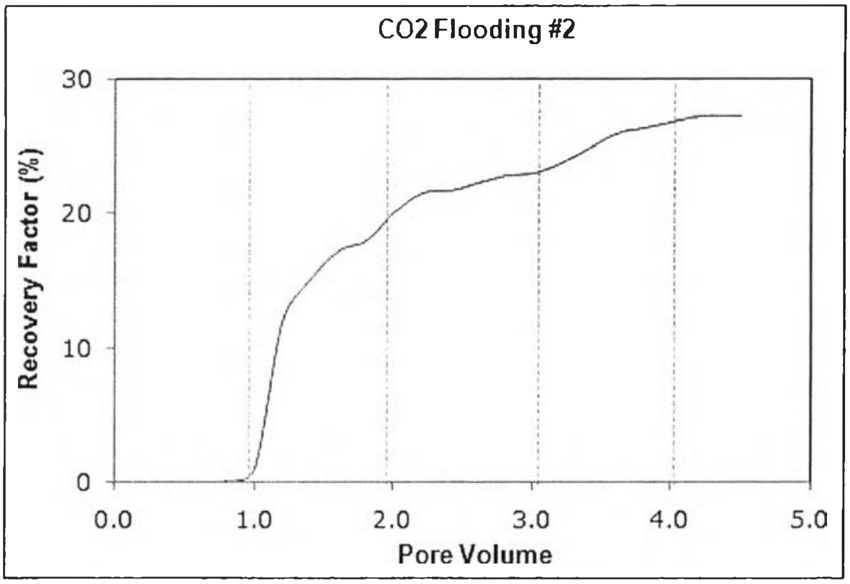

Figure A5 The simulation result of carbon dioxide flooding with high permeability sand pack of 38.6 dar6y and high oil viscosity of 1500 cp.

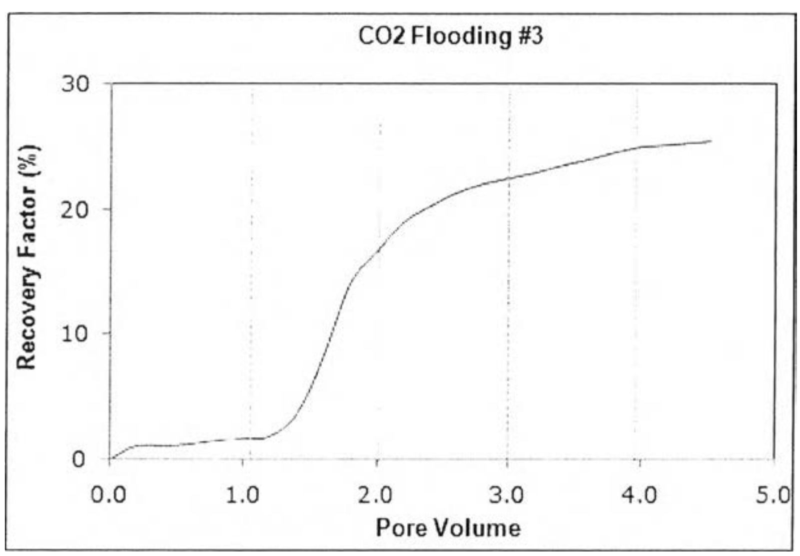

Figure A6 The simulation result of carbon dioxide flooding with low permeability sand pack of 11.4 darcy and high oil viscosity of 1500 cp.

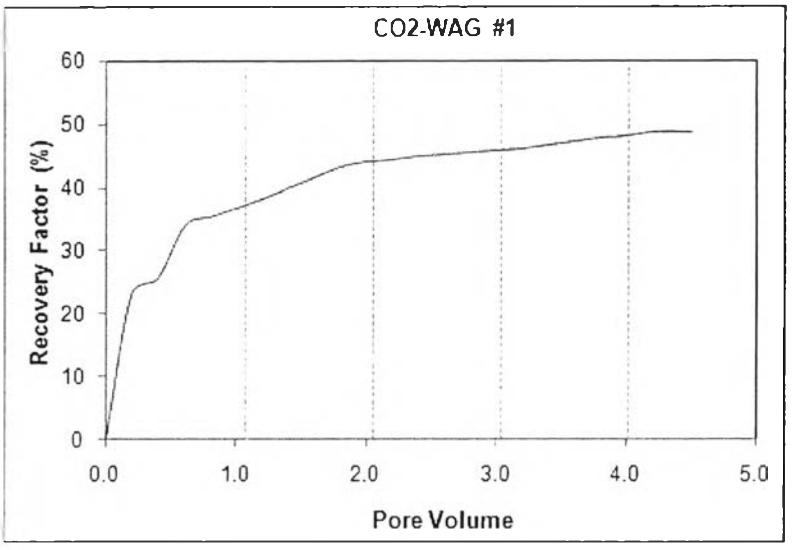

Figure A7 The simulation result of water-alternating-carbon dioxide with high permeability sand pack of 43 darcy, low oil viscosity of 440 cp and CO_2/water slug ratio of 1:1.

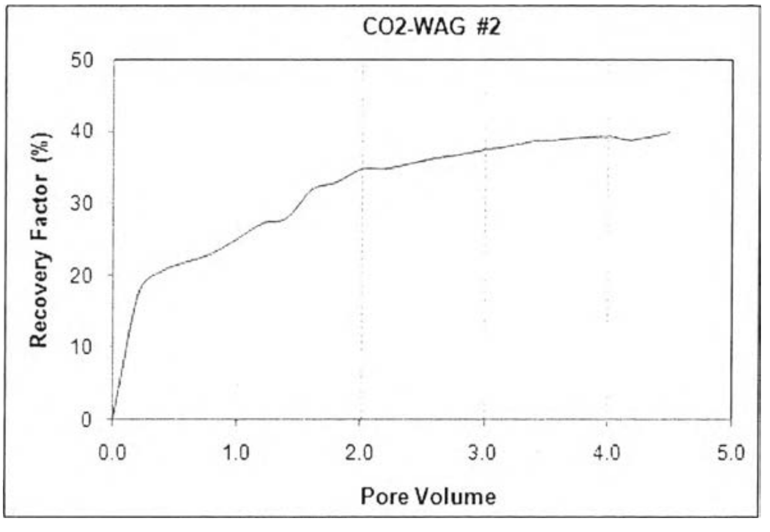

Figure A8 The simulation result of water-alternating-carbon dioxide with high permeability sand pack of 40.6 darcy, high oil viscosity of 1500 cp and CO_2/water slug ratio of 1:1.

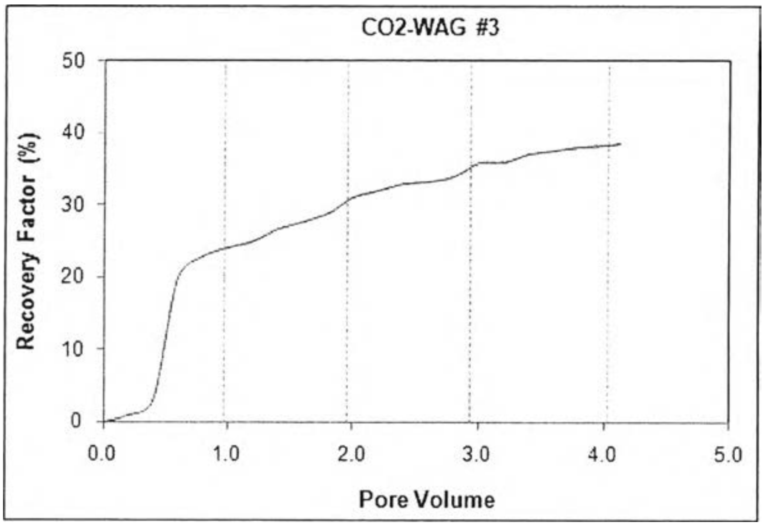

Figure A9 The simulation result of water-alternating-carbon dioxide with low permeability sand pack of 12.6 darcy, high oil viscosity of 1500 cp and CO_2/water slug ratio of 1:1.

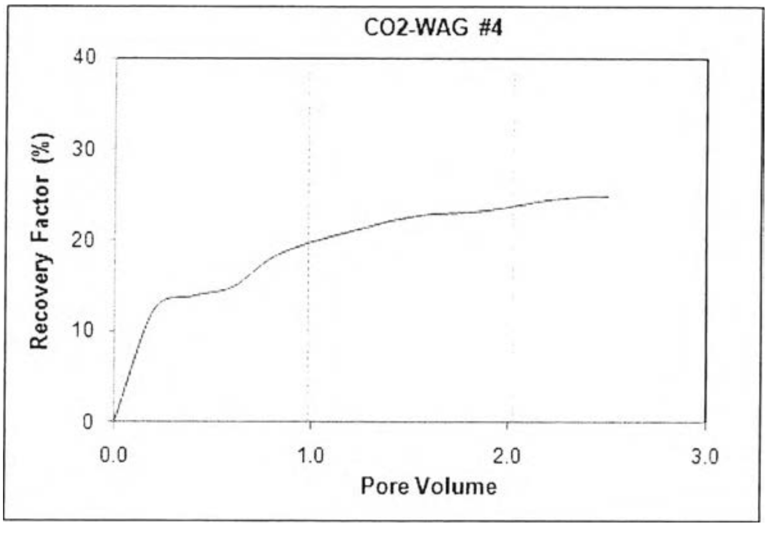

Figure A10 The simulation result of water-alternating-carbon dioxide with high permeability sand pack of 41.9 darcy, high oil viscosity of 1500 cp and CO_2/water slug ratio of 1:2.

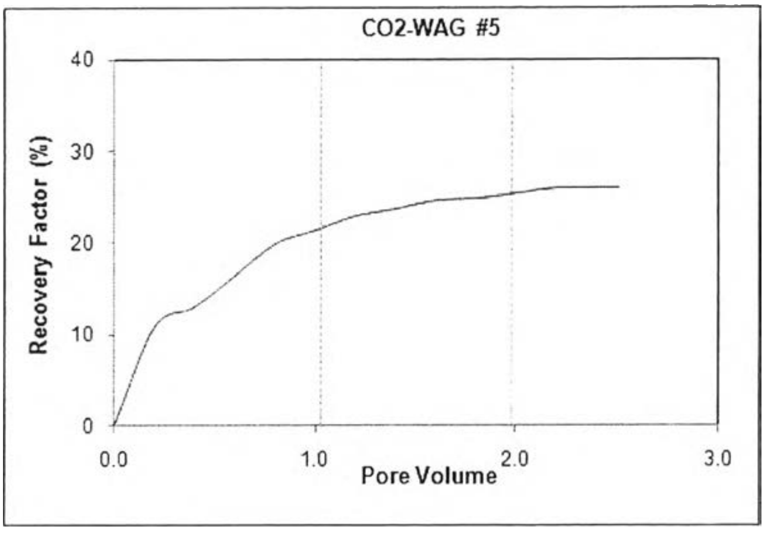

Figure A11 The simulation result of water-alternating-carbon dioxide with high permeability sand pack of 41.95 darcy, low oil viscosity of 1500 cp and CO_2/water slug ratio of 2:1.

Appendix B Simulation Steps of Three Recovery Methods

The following data are presented the simulation steps of waterflooding, carbon dioxide flooding and water-alternating-carbon dioxide, respectively.

B1 Simulation Steps of Waterflooding

) Click Reservoir package.

2) Click Create grid.

3) Click Cartesian.

4) Insert I-direction, J-direction and K-direction equal to 1.

5) Insert block width for I-direction equals to 0.0257 meters.

6) Insert block width for J-direction equals to 0.0955 meters.

7) Click Reservoir package.

8) Click Edit grid.

9) Click Refinement wizard.

10) Select Current Fundamental Layer.

11) Select Cartesian option.

12) Insert 10 in the block of j-direction for refinement j-direction.

13) Click Reservoir package.

14) Click Edit grid.

15) Click Refinement wizard.

16) Select Hybrid option

17) Select Radial equals to 10 for refinement r-direction.

18) Select Along well equals to 4 for refinement j-direction.

19) Select Theta equals to 4 for refinement θ-direction.

20) Select K-direction in the wellbore parallel option.

21) Click Specify property

22) Insert porosity, permeability I, permeability J and permeability K equal to the value in the experimental data.

23) Click Components package.

24) Click Imex PVT Regions.

25) Select water and oil.

26) Insert reservoir temperature, reservoir pressure and API gravity equal to the value in the experimental data.

27) Click Rock-Fluid package.

28) Click Rock types.

29) Select Relative permeability correlations.

30) Select the function of unconsolidated sandstone.

31) Insert connate water saturation (S_{wc}), original oil saturation (S_{or}).

32) Click Initial Conditions package.

33) Select water, oil option.

34) Insert reference pressure and depth equals to 345 kpa and 0.01285 meters, respectively.

35) Insert depth of water-oil contact equals to 0.01285 meters.

36) Click Wells& Recurrent option.

37) Click Create new well.

38) Create water injection well.

39) Insert water injector as a name in the option of ID & type.

40) Click Constraints.

41) Select parameter as BHW reservoir water rate.

42) Insert injection rate as same as the experimental procedure.

43) Create production well.

44) Insert producer as a name in the option of ID & type.

45) Create production well.

46) Click Constraints.

47) Select parameter as Minimum bottom hole pressure.

48) Insert Minimum bottom hole equal to 200 kPa.

49) Click Wells& Recurrent option

50) Click Perforate.

51) Perforate water injector at (1,1,1/1,10,1/1,1,4).

52) Perforate producer at (1,1,1/1,1,1/1,1,1)

53) Click Wells & Recurrent.

54) Click Dates.

55) Select range of date.

56) Select steps as hour.

57) Save this file.

58) Run this file with IMEX module.

59) Create graph between pore volume and recovery factor from Result CMG.

B2 Simulation Steps of Carbon Dioxide Flooding

1) Click Reservoir package.

2) Click Create grid.

3) Click Cartesian.

4) Insert I-direction, J-direction and K-direction equal to 1.

5) Insert block width for I-direction equals to 0.0257 meters.

6) Insert block width for J-direction equals to 0.0955 meters.

7) Click Reservoir package.

8) Click Edit grid.

9) Click Refinement wizard.

10) Select Current Fundamental Layer.

11) Select Cartesian option.

12) Insert 10 in the block of j-direction for refinement j-direction.

13) Click Reservoir package.

14) Click Edit grid.

15) Click Refinement wizard.

16) Select Hybrid option

17) Select Radial equals to 10 for refinement r-direction.

18) Select Along well equals to 4 for refinement j-direction.

19) Select Theta equals to 4 for refinement θ-direction.

20) Select K-direction in the wellbore parallel option.

21) Click Specify property

22) Insert porosity, permeability I, permeability J and permeability K equal to the value in the experimental data.

23) Click Components package.

24) Click Imex PVT Regions.

25) Select miscible option.

26) Insert carbon dioxide density.

27) Insert the value of gas and solvent mixing parameter equals to zero (immiscible condition)

28) Insert reservoir temperature, reservoir pressure and API gravity equal to the value in the experimental data.

29) Click Rock-Fluid package.

30) Click Rock types.

31) Select Relative permeability correlations.

32) Select the function of unconsolidated sandstone.

33) Insert connate water saturation (S_{wc}), original oil saturation (S_{or}).

34) Click Initial Conditions package.

35) Select water, oil and gas option.

36) Insert reference pressure and depth equals to 345 kpa and 0.01285 meters, respectively.

37) Insert depth of water-oil contact equals to 0.01285 meters.

38) Click Wells & Recurrent option.

39) Click Create new well.

40) Create solvent injection well.

41) Insert solvent injector as a name in the option of ID & type.

42) Click Constraints.

43) Select parameter as BHS reservoir solvent rate.

44) Insert injection rate as same as the experimental procedure.

45) Create production well.

46) Insert producer as a name in the option of ID & type.

47) Create production well.

48) Click Constraints.

49) Select parameter as Minimum bottom hole pressure.

50) Insert Minimum bottom hole equal to 200 kPa.

51) Click Wells & Recurrent option

52) Click Perforate.

53) Perforate solvent injector at (1,1,1/1,10,1/1,1,4).

54) Perforate producer at (1,1,1/1,1,1/1,1,1)

55) Click Wells & Recurrent.

56) Click Dates.

57) Select range of date.

58) Select steps as hour.

59) Save this file.

60) Run this file with IMEX module.

61) Create graph between pore volume and recovery factor from Result CMG.

B3 Simulation Steps of Water-Alternating-Carbon Dioxide

1) Click Reservoir package.

2) Click Create grid.

3) Click Cartesian.

4) Insert I-direction, J-direction and K-direction equal to 1.

5) Insert block width for I-direction equals to 0.0257 meters.

6) Insert block width for J-direction equals to 0.0955 meters.

7) Click Reservoir package.

8) Click Edit grid.

9) Click Refinement wizard.

10) Select Current Fundamental Layer.

11) Select Cartesian option.

12) Insert 10 in the block of j-direction for refinement j-direction.

13) Click Reservoir package.

14) Click Edit grid.

15) Click Refinement wizard.

16) Select Hybrid option

17) Select Radial equals to 10 for refinement r-direction.

18) Select Along well equals to 4 for refinement j-direction.

19) Select Theta equals to 4 for refinement θ-direction.

20) Select K-direction in the wellbore parallel option.

21) Click Specify property

22) Insert porosity, permeability I, permeability J and permeability K equal to the value in the experimental data.

23) Click Components package.

24) Click Imex PVT Regions.

25) Select miscible option.

26) Insert carbon dioxide density.

27) Insert the value of gas and solvent mixing parameter equals to zero (immiscible condition)

28) Insert reservoir temperature, reservoir pressure and API gravity equal to the value in the experimental data.

29) Click Rock-Fluid package.

30) Click Rock types.

31) Select Relative permeability correlations.

32) Select the function of unconsolidated sandstone.

33) Insert connate water saturation (S_{wc}), original oil saturation (S_{or}).

34) Click Initial Conditions package.

35) Select water, oil and gas option.

36) Insert reference pressure and depth equals to 345 kpa and 0.01285 meters, respectively.

37) Insert depth of water-oil contact equals to 0.01285 meters.

38) Click Wells & Recurrent option.

39) Click Create new well.

40) Create water injection well.

41) Insert water injector as a name in the option of ID & type.

42) Click Constraints.

43) Select parameter as BHW reservoir water rate.

44) Insert injection rate as same as the experimental procedure.

45) Create solvent injection well.

46) Insert solvent injector as a name in the option of ID & type.

47) Click Constraints.

48) Select parameter as BHS reservoir solvent rate.

49) Insert injection rate as same as the experimental procedure.

50) Create production well.

51) Insert producer as a name in the option of ID & type.

52) Create production well.

53) Click Constraints.

54) Select parameter as Minimum bottom hole pressure.

55) Insert Minimum bottom hole equal to 200 kPa.

56) Click Dates

57) Select range of date

58) Select step as hour.

59) Click Wells

60) Click options

61) Set the constraints as same as the experimental procedure.

62) Click Wells & Recurrent option

63) Click Perforate.

64) Perforate solvent injector at (1,1,1/1,10,1/1,1,4).

65) Perforate producer at (1,1,1/1,1,1/1,1,1)

66) Click Wells & Recurrent.

67) Click Dates.

68) Select range of date.

69) Select steps as hour.

70) Save this file.

71) Run this file with IMEX module.

72) Create graph between pore volume and recovery factor from Result CMG.

CURRICULUM VITAE

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Proceedings:

1. Teerasukakul, W.; Torabi, F.; and Saiwan, C. (2013, April 23) Simulation of Waterflooding, Carbon Dioxide Flooding and Water-Alternating-Carbon Dioxide in Heavy Oil Reservoir: Comparative Evaluation. Proceedings of the 4^{th} Research Symposium on Petrochemicals and Materials Technology and The 19^{th} PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.
2. Teerasukakul, W.; Torabi, F.; and Saiwan, C.(2013, September 29-October2) Simulation of Waterflooding, Carbon Dioxide Flooding and Water-Alternating-Carbon Dioxide in Heavy Oil Reservoir: Comparative Evaluation. The 16^{th}Conference Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction, Rhodes Island, Greece.