

Hyperlinks for Report Figure to Spreadsheet Plot Location

Report Figure Number

[Figure 5.13](#)

[Figure 5.14](#)

[Figure 5.15](#)

[Figure 5.16](#)

[Figure 5.17](#)

[Figure 5.18](#)

[Figure 5.19](#)

[Figure 5.20](#)

[Figure 5.21](#)

[Figure 5.22](#)

[Figure 5.23](#)

[Figure 5.24](#)

[Figure 5.25](#)

[Figure 5.26](#)

[Figure 5.27](#)

[Figure 5.28](#)

[Figure 5.29](#)

Interpolated

| Org | OrgCode | LCS [deg] | ICOD [mm] | MCOD [mm] | OCOD [mm] | CBM_NO kN-r | CCS [deg] | LR kg/s | IDCOD [mm] | MWCOD [mm] | ODCOD [mm] | Comments |
|--------------------------------------------|----------|-----------|-----------|-----------|-----------|-------------|-----------|--------------|-------------|-------------|---------------------|---------------------------|
| DPS9, 150 mm OD, 1 gpm | | | | | | | | | | | | |
| CEI | | 82.2 | 0.076 | 0.089 | 0.101 | 53.5 | 156.4 | 0.767 | 0.339 | 0.367 | 0.396 | Free,TP |
| CRIEPI | | 67.1 | | 0.100 | | 57.6 | 158.0 | 5.702 | | 0.888 | | Free,TP |
| KIWA | | 69.5 | 0.078 | 0.095 | 0.113 | 39.7 | 127.0 | 1.283 | 0.366 | 0.421 | 0.476 | Free,TP |
| NRC | | 68.9 | 0.087 | 0.104 | 0.121 | 69.1 | 171.0 | 5.156 | 0.856 | 0.938 | 1.020 @ 1 (0.063) g | Free,TP |
| SIA | | 77.6 | 0.079 | 0.093 | 0.108 | 59.2 | 175.7 | 785.527 | 3.922 | 4.205 | 4.488 | Free,TP |
| | average | 73.0 | | | | | 157.6 | | | | | |
| | st. dev. | 6.5 | | | | | 19.0 | | | | | |
| DPS12, 150 mm OD, 1 gpm, WRS3 | | | | | | | | | | | | |
| CEI | | 78.2 | 0.099 | 0.086 | 0.074 | 55.6 | 156.4 | 0.992 | 0.461 | 0.479 | 0.498 | Free, TP, WRS3 |
| CRIEPI | | 74.5 | 0.089 | 0.109 | 0.128 | 37.0 | 126.3 | 1.176 | 0.360 | 0.414 | 0.469 | Free, TP, WRS3 |
| KIWA | | 77.9 | 0.137 | 0.099 | 0.063 | 64.2 | 171.0 | 4.270 | 0.797 | 0.836 | 0.877 @ 1 (0.063) g | Free, TP, WRS3 |
| NRC | | | | | | | | | | | | Free, TP, WRS3 |
| SIA | | | | | | | | | | | | Free, TP, WRS3 |
| | average | 76.9 | | | | | 151.2 | | | | | |
| | st. dev. | 2.0 | | | | | 22.8 | | | | | |
| ERPC5, 150 mm OD, free | | | | | | | | | | | | |
| CEI | | 91.2 | 0.070 | 0.081 | 0.093 | 48.6 | 163.8 | 0.720 | 0.306 | 0.330 | 0.353 | Free |
| CRIEPI | | 76.5 | | 0.090 | | 52.9 | 166.0 | 3.478 | | 0.734 | | Free |
| KIWA | | 79.9 | 0.073 | 0.088 | 0.104 | 39.8 | 140.5 | 1.487 | 0.391 | 0.444 | 0.497 | Results from F |
| NRC | | 78.1 | 0.079 | 0.094 | 0.109 | 64.1 | 178.0 | 3.420 | 0.737 | 0.805 | 0.873 | 2c Margin: 2.2 |
| SIA | | 77.6 | 0.079 | 0.093 | 0.108 | 59.2 | 175.7 | 49.488 | 3.922 | 4.205 | 4.488 | Free |
| | average | 80.7 | | | | | 164.8 | | | | | |
| | st. dev. | 6.0 | | | | | 14.9 | | | | | |
| ERPC6, 150 mm OD, ER1 | | | | | | | | | | | | |
| CEI | | 133.3 | 0.055 | 0.061 | 0.067 | 61.9 | | | | | | ER1 |
| CRIEPI | | 83.8 | | 0.084 | | 49.3 | | | | | | ER1 |
| KIWA-FE | | 120.9 | 0.057 | 0.065 | 0.073 | | | | | | | Results from F ER1 |
| NRC | | 93.5 | 0.069 | 0.081 | 0.094 | 75.1 | 312.0 | | | | | RC: 0.817, 2c N ER1 |
| SIA | | 69.5 | 0.085 | 0.102 | 0.118 | 78.6 | 317.5 | | | | | CCS is too long ER1 |
| | average | 100.2 | | | | | 314.8 | | | | | |
| | st. dev. | 26.4 | | | | | 3.9 | | | | | |
| ERPC7, 150 mm OD, ER2 | | | | | | | | | | | | |
| CEI | | 117.8 | 0.060 | 0.067 | 0.075 | 49.0 | | | | | | ER2 |
| CRIEPI | | 77.7 | | 0.089 | | 52.3 | | | | | | ER2 |
| KIWA-FE | | 107.1 | 0.061 | 0.071 | 0.082 | | | | | | | Results from F ER2 |
| NRC | | 91.4 | 0.070 | 0.083 | 0.096 | 66.2 | 282.0 | | | | | RC: 0.942, 2c N ER2 |
| SIA | | 68.7 | 0.083 | 0.101 | 0.119 | 70.7 | 265.8 | | | | | CCS is too long ER2 |
| | average | 92.5 | | | | | 273.9 | | | | | |
| | st. dev. | 20.2 | | | | | 11.5 | | | | | |
| ERPC8, 150 mm OD, ER1, WRS3 | | | | | | | | | | | | |
| CEI | | | | | | | | | | | | ER1, WRS3 |
| CRIEPI | | | | | | | | | | | | ER1, WRS3 |
| KIWA | | | | | | | | | | | | ER1, WRS3 |
| NRC | | 114.8 | 0.129 | 0.085 | 0.042 | 74.3 | 312.0 | 75000000.000 | 2955004.000 | 3121674.000 | 3248151.000 | RC: 0.714, 2c N ER1, WRS3 |
| SIA | | | | | | | | | | | | ER1, WRS3 |
| ERPC8*, 150 mm OD, Free, WRS3 | | | | | | | | | | | | |
| CEI | | | | | | | | | | | | Free, WRS3 |
| CRIEPI | | | | | | | | | | | | Free, WRS3 |
| KIWA | | 110.7 | 0.022 | 0.026 | 0.030 | 33.3 | 170.5 | 0.670 | 0.332 | 0.348 | 0.364 | Results from F Free, WRS3 |
| NRC | | | | | | | | | | | | Free, WRS3 |
| SIA | | | | | | | | | | | | Free, WRS3 |
| ERPC5*, 150 mm OD, 1gpm; WRS3, Free | | | | | | | | | | | | |
| CEI | | | | | | | | | | | | Free, WRS3 |
| CRIEPI | | | | | | | | | | | | Free, WRS3 |
| KIWA | | 85.7 | 0.098 | 0.091 | 0.085 | 36.8 | 139.1 | 0.810 | 0.369 | 0.396 | 0.423 | Results from F Free, WRS3 |
| NRC | | | | | | | | | | | | Free, WRS3 |
| SIA | | | | | | | | | | | | Free, WRS3 |
| %difference in KIWA results d | | 22.584 | -337.651 | -248.171 | -183.819 | -10.511 | 18.416 | -20.896 | -10.925 | -13.618 | -16.073 | |

| ERP/DP | S9 Margin | Ratio | LCS_LR/LC | CCS_LR/C | CS_COA | kg/s/cm^2 | MWCOD/LCS | MWCOD/CCS | OCOD/CCS | OD (mm) | CBM/(pi)(t*Ro^2) | MPa | CBM/(pi)-LCS*(t*Ro^2) | MPa |
|----------|-----------|----------|-----------|----------|----------|-----------|-----------|-----------|----------|----------|------------------|-----|-----------------------|-----|
| 0.943131 | 0.921536 | 0.9623 | 9.16E-01 | 1.41E+00 | 8.95E-01 | 1.95E+00 | 1.904189 | 252.2227 | 150 | 6.880089 | 410.7073 | | | |
| 9.93E-01 | 4.30E+00 | 1.24E+00 | 4.67E+00 | 2.354694 | 271.6244 | 150 | 6.346567 | 407.2331 | 150 | 6.265563 | 284.3166 | | | |
| 1.01E+00 | 2.54E+00 | 1.14E+00 | 2.75E+00 | 1.827338 | 187.0429 | 150 | 6.265563 | 284.3166 | 150 | 6.265563 | 284.3166 | | | |
| 9.30E-01 | 3.40E+00 | 1.25E+00 | 4.55E+00 | 2.481858 | 325.855 | 150 | 6.77749 | 493.6248 | 150 | 6.77749 | 493.6248 | | | |
| 9.19E-01 | 1.12E+02 | 1.00E+00 | 1.99E+01 | 2.265427 | 279.3723 | 150 | 6.85301 | 444.0455 | 150 | 6.85301 | 444.0455 | | | |

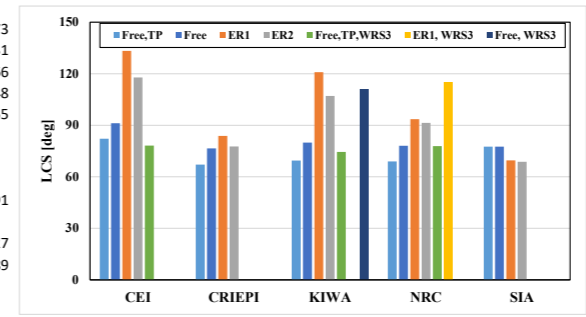


Figure 5.26

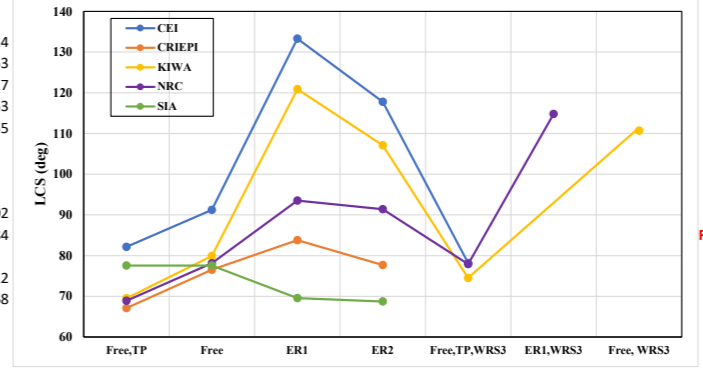


Figure 5.27

| LCS | CEI | CRIEPI | KIWA | NRC | SIA |
|--------------|-------|--------|-------|-------|------|
| Free,TP | 82.2 | 67.1 | 69.5 | 68.9 | 77.6 |
| Free | 91.2 | 76.5 | 79.9 | 78.1 | 77.6 |
| ER1 | 133.3 | 83.8 | 120.9 | 93.5 | 69.5 |
| ER2 | 117.8 | 77.7 | 107.1 | 91.4 | 68.7 |
| Free,TP,WRS3 | 78.2 | | 74.5 | 77.9 | |
| ER1,WRS3 | | | | 114.8 | |
| Free,WRS3 | | | 110.7 | | |

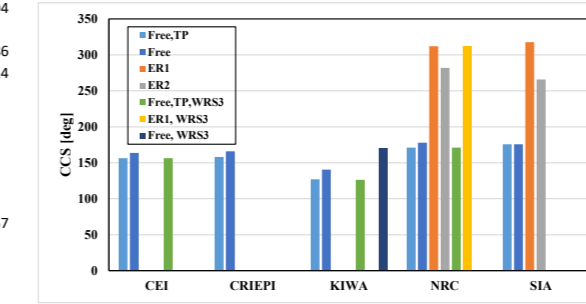
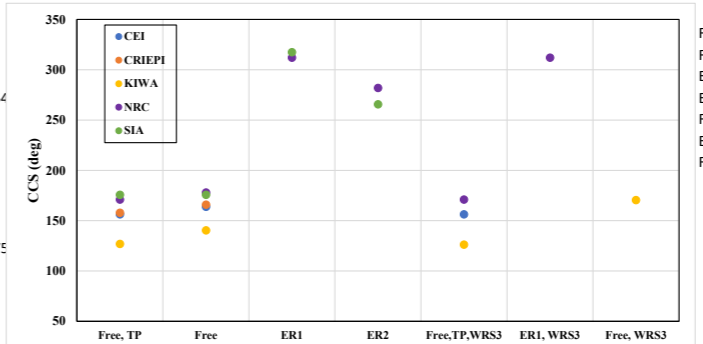


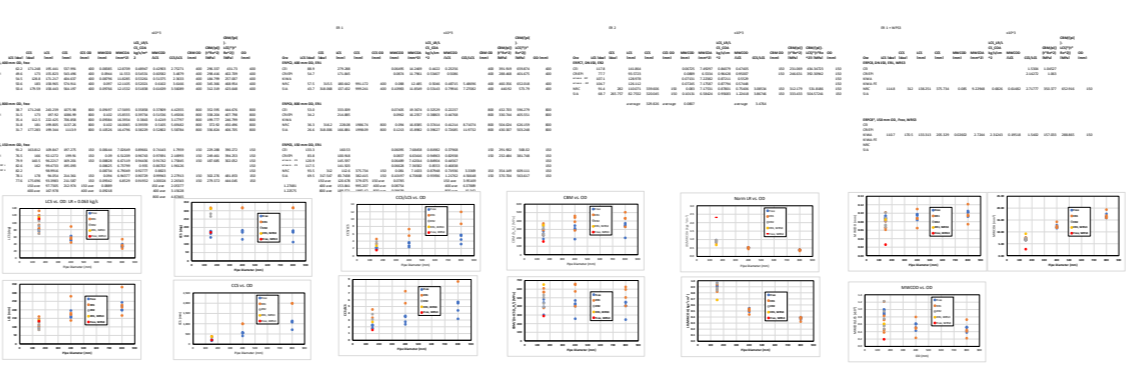
Figure 5.28



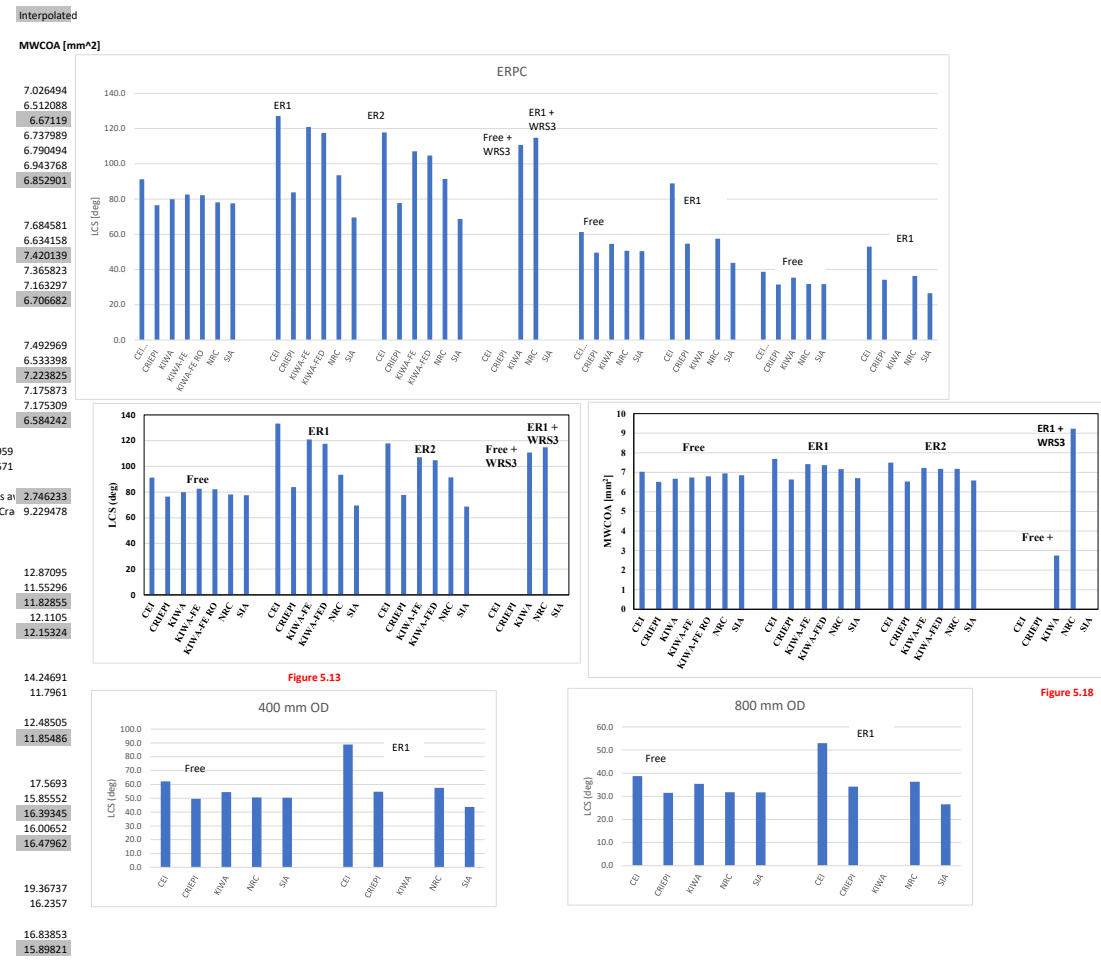
| CCS | CEI | CRIEPI | KIWA | NRC | SIA |
|--------------|-------|--------|-------|-------|-------|
| Free,TP | 117.8 | 77.7 | 79.9 | 78.1 | 77.6 |
| Free | 163.8 | 166.0 | 140.5 | 178.0 | 175.7 |
| ER1 | 156.4 | | 126.3 | 312.0 | 317.5 |
| ER2 | | | | 282.0 | 265.8 |
| Free,TP,WRS3 | 156.4 | | 126.3 | 171.0 | |
| ER1,WRS3 | | | | 312.0 | |
| Free,WRS3 | | | 170.5 | | |

Figure 5.29

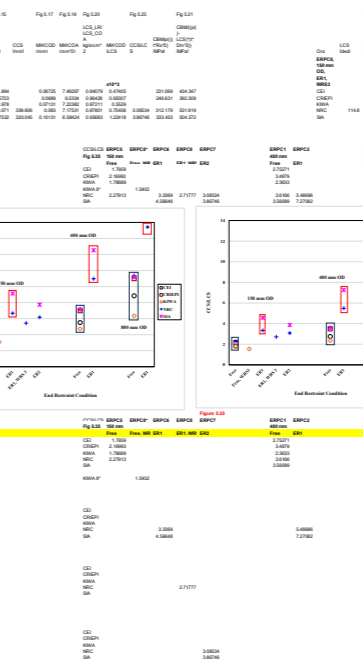
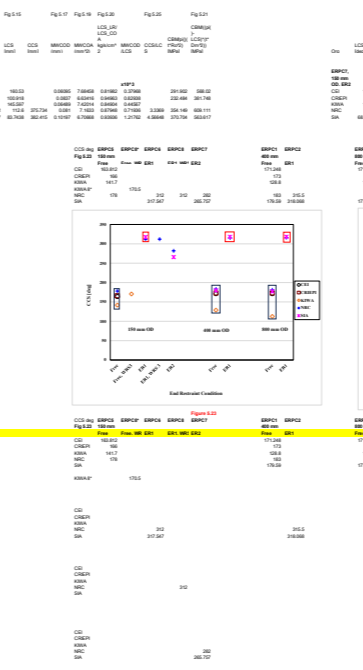
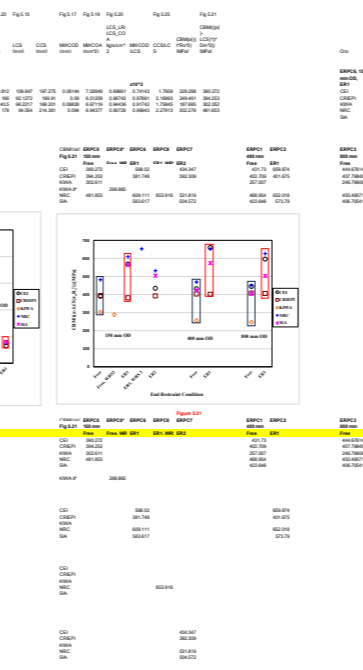
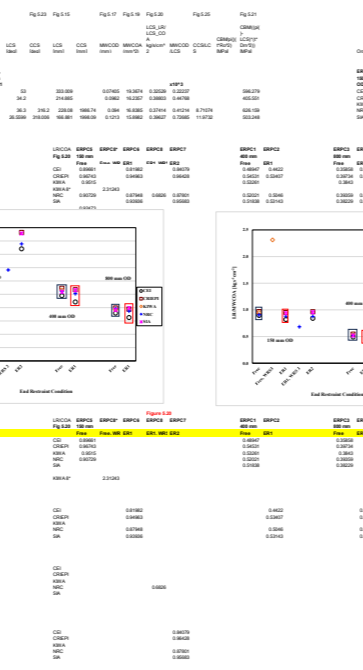
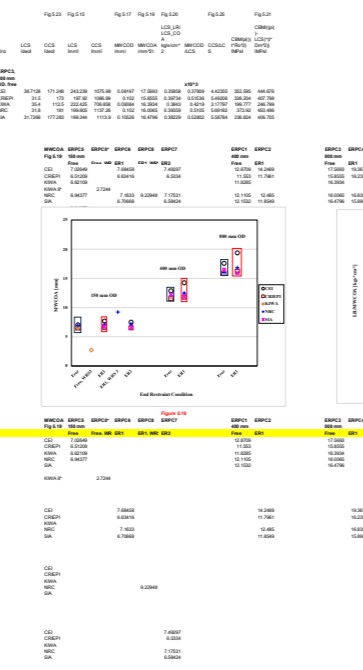
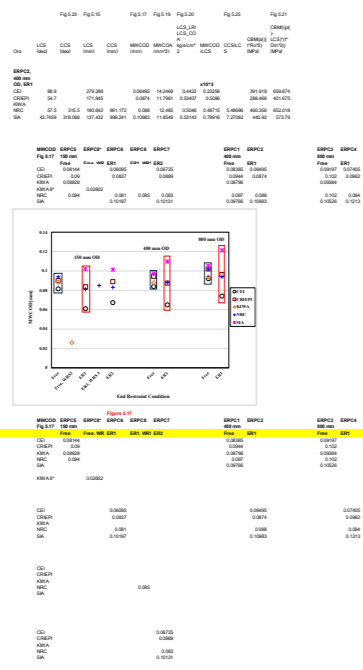
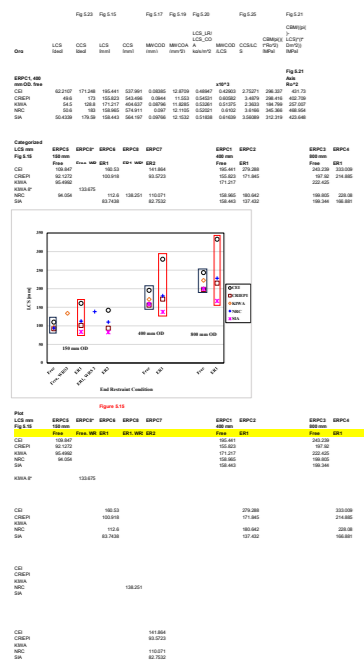
| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|------------|------|------|------|------|------|------|------|------|------|------|------|
| Admission | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Retention | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Graduation | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Dropout | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Transfer | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |



| ERP Submaster | OD | Org | Interpolated | | | | | Interpolated | | | | | Comments |
|------------------------------------------|------------|-------|--------------|-----------|-----------|-----------|-----------|-------------------|---------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| | | | LCS [deg] | IDCOD [m] | MWCOD [m] | ODCOD [m] | CBM_NO kh | CCS_SSE [deg] | LR_CCS kg/s | IDCOD [mm] | MWCOD [mm] | ODCOD [mm] | |
| ERPC5, 150 mm OD, 1 gpm; No, Free 150 mm | CEI | 91.2 | 0.070 | 0.081 | 0.093 | 48.6 | 163.8 | 0.720 | 0.306 | 0.330 | 0.353 | 0.49681 Results from ISAAC/LBBPipe Results from FEM/ExcelSQUIRT. Values are given for LE analyses Results from FEM/ExcelSQUIRT. Values are given for RO analyses 2c Margin: 2.29, BM Margin: 4.45 4.488 | |
| | CRIEPI | 76.5 | | 0.090 | | 52.9 | 166.0 | | | 0.734 | | | |
| | KIWA | 79.9 | 0.073 | 0.088 | 0.104 | 39.8 | 140.5 | 1.487 | 0.39127 | 0.444 | | | |
| | KIWA-FE | 82.6 | 0.072 | 0.086 | 0.100 | | | | | | | | |
| | KIWA-FE RO | 82.2 | 0.073 | 0.087 | 0.101 | | 162.0 | | | | | | |
| | NRC | 78.1 | 0.079 | 0.094 | 0.109 | 64.1 | 178.0 | 3.420 | 0.737 | 0.805 | | | |
| SIA | 77.6 | 0.079 | 0.093 | 0.108 | 59.2 | 175.7 | 49.488 | 3.922 | 4.205 | | | | |
| ERPC6, 150 mm OD, 1 gpm; No, ER1 | CEI | 133.3 | 0.055 | 0.061 | 0.067 | 61.9 | | | | | Results from FEM/ExcelSQUIRT. Only values from LE analyses are provided Results from FEM/ExcelSQUIRT. Only values from LE analyses are provided RC: 0.817, 2c Margin: 3.34, BM Margin: 4.83, CBM SigB = 495 MPa CCS is too long such that LR is not valid. | | |
| | CRIEPI | 83.8 | | 0.084 | | 49.3 | | | | | | | |
| | KIWA-FE | 120.9 | 0.057 | 0.065 | 0.073 | | | | | | | | |
| | KIWA-FED | 117.5 | 0.058 | 0.066 | 0.075 | | | | | | | | |
| | NRC | 93.5 | 0.069 | 0.081 | 0.094 | 82.3 | 312.0 | | | | | | |
| SIA | 69.5 | 0.085 | 0.102 | 0.118 | 78.6 | 317.5 | | | | | | | |
| ERPC7, 150 mm OD, 1 gpm; No, ER2 | CEI | 117.8 | 0.060 | 0.067 | 0.075 | 49.0 | | | | | Results from FEM/ExcelSQUIRT. Only values from LE analyses are provided Results from FEM/ExcelSQUIRT. Only values from LE analyses are provided RC: 0.942, 2c Margin: 3.08, BM Margin: 4.30, CBM SigB = 440 MPa (/Z) CCS is too long such that LR is not valid. | | |
| | CRIEPI | 77.7 | | 0.089 | | 52.3 | | | | | | | |
| | KIWA-FE | 107.1 | 0.061 | 0.071 | 0.082 | | | | | | | | |
| | KIWA-FED | 104.7 | 0.062 | 0.072 | 0.083 | | | | | | | | |
| | NRC | 91.4 | 0.070 | 0.083 | 0.096 | 72.2 | 282.0 | | | | | | |
| SIA | 68.7 | 0.083 | 0.101 | 0.119 | 70.7 | 265.8 | | | | | | | |
| ERPC8, 150 mm OD, 1 gpm, ER1, WRS3 | CEI | | | | | | | 0.050626 | ave. 6.983959 | | | Results from ISAAC/LBBPipe. See report for description of this analysis; CCS is a RC: 0.714, 2c Margin: 2.72, BM Margin: 4.36, CBM SigB = 447 MPa; OD WRS Cra | |
| | CRIEPI | | | | | | | st. dev. 0.353571 | | | | | |
| | KIWA | 110.7 | 0.022 | 0.026 | 0.030 | 33.3 | 170.5 | 0.670 | 0.332 | 0.348 | 0.364 | | |
| | NRC | 114.8 | 0.129 | 0.085 | 0.042 | 74.3 | 312.0 | 7500000.000 | 2955004.000 | 3121674.000 | 3248151.000 | | |
| | SIA | | | | | | | | | | 9.229478 | | |
| ERPC1, 400 mm OD, 1 gpm; No, Free 400 mm | CEI | 62.2 | 0.070 | 0.084 | 0.097 | 1489.6 | 171.2 | 4.339 | 0.598 | 0.658 | 0.719 | Results from ISAAC/LBBPipe 2c Margin: 3.62, BM Margin: 6.11 7.181 | |
| | CRIEPI | 49.6 | | 0.094 | | 1500.0 | 173.0 | 5.607 | | 1.670 | | | |
| | KIWA | 54.5 | 0.069 | 0.088 | 0.107 | 928.9 | 128.8 | 3.087 | 0.553 | 0.653 | | | |
| | NRC | 50.6 | 0.081 | 0.097 | 0.115 | 1736.0 | 183.0 | 12.270 | 1.784 | 1.970 | | | |
| | SIA | 50.4 | 0.081 | 0.098 | 0.115 | 1569.9 | 179.6 | 157.414 | 6.010 | 6.595 | | | |
| | | | | | | | | | | | 12.87095 | | |
| ERPC2, 400 mm OD, 1 gpm; No, ER1 | CEI | 88.9 | 0.054 | 0.065 | 0.076 | 1970.0 | | | | | Not analyzed RC: 0.856, 2c Margin: 5.48, BM Margin: 5.33, CBM SigB = 624 MPa CCS is too long such that LR is not valid. | | |
| | CRIEPI | 54.7 | | 0.087 | | 1450.0 | | | | | | | |
| | KIWA | | | | | | | | | | | | |
| | NRC | 57.5 | 0.072 | 0.088 | 0.106 | 2314.0 | 315.5 | | | | | | |
| | SIA | 43.7 | 0.089 | 0.110 | 0.130 | 2216.3 | 318.1 | | | | | | |
| ERPC3, 800 mm OD, 1 gpm; No, Free 800 mm | CEI | 38.7 | 0.078 | 0.092 | 0.106 | 14178.7 | 171.2 | 13.114 | 1.196 | 1.317 | Results from ISAAC/LBBPipe 2c Margin: 5.68, BM Margin: 5.98 12.108 | | |
| | CRIEPI | 31.5 | | 0.102 | | 13600.0 | 173.0 | 16.632 | | 3.340 | | | |
| | KIWA | 35.4 | 0.075 | 0.094 | 0.113 | 8033.5 | 112.5 | 5.252 | 0.727 | 0.872 | | | |
| | NRC | 31.8 | 0.088 | 0.102 | 0.123 | 14996.0 | 181.0 | 31.420 | 2.981 | 3.314 | | | |
| | SIA | 31.7 | 0.088 | 0.105 | 0.123 | 13544.5 | 177.3 | 474.287 | 10.028 | 11.068 | | | |
| | | | | | | | | | | | | 17.5693 | |
| ERPC4, 800 mm OD, 1 gpm; No, ER1 | CEI | 53.0 | 0.060 | 0.074 | 0.088 | 17400.0 | | | | | Not analyzed RC: 0.889, 2c Margin: 8.7 BM Margin: 6.69, CBM SigB = 683 MPa CCS is too long such that LR is not valid. | | |
| | CRIEPI | 34.2 | | 0.096 | | 13300.0 | | | | | | | |
| | KIWA | | | | | | | | | | | | |
| | NRC | 36.3 | 0.076 | 0.094 | 0.115 | 20268.0 | 316.2 | | | | | | |
| | SIA | 26.6 | 0.100 | 0.121 | 0.143 | 17303.7 | 318.0 | | | | | | |
| ERPC5*, 150 mm OD, 1gpm; WRS3, Free | CEI | | | | | | | | | | Results from ISAAC/LBBPipe. See report for description of this analysis | | |
| | CRIEPI | | | | | | | | | | | | |
| | KIWA | 85.7 | 0.098 | 0.091 | 0.085 | 36.8 | 139.100 | 0.810 | 0.369 | 0.396 | | | |
| | NRC | | | | | | | | | | | | |
| | SIA | | | | | | | | | | | | |



21.4
-1.0
1.226



| | | | | | |
|-----------------------------|------------------|-------------------------|----------|-----------------|----------|
| Participating Organization: | Candu Energy Inc | Analyst Identification: | Min Wang | Reporting Date: | 9-Sep-22 |
|-----------------------------|------------------|-------------------------|----------|-----------------|----------|

Codes and Procedures Used in Analysis (add space as needed)

| Name and Version # | List any code or analysis limitations for these problems (e.g., utilizes flat-plate K-solutions) | List any analysis assumptions | Briefly describe the approach that your code or analysis uses to determine output variables (e.g., COD, CBM) | Briefly describe the approach used to incorporate WRS within the evaluation | Provide any other comments related to your code capabilities or evaluation approach that affects your results |
|---------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| COD Code(s) AP3 Version 1.0 | 1. Crack face pressure is 100%; customized to 50% for benchmark problem. 2. No evaluation of LCS: customized to manually evaluate. 3. No evaluation of CBM: independently calculated using EXCEL. 4. No evaluation for restraint condition: independently calculated | Shape of crack opening is elliptical | Elastic COA solution for circumferential cracks in cylinder, Article | | |
| Leak Rate Code(s) LEAPOR-Candu | 1. Not applicable to single phase steam 2. Code does not converge for some cases | Use SQURT (Excel version) | | | |
| Crack Stability Code(s) AP3 Version 1.0 | | Material is ductile. | Net-section collapse is used. | WRS is not involved in crack stability. | |

Crack Morphology Modeling (add space as needed)

| Briefly describe your crack morphology model (if using a NUREG/CR-6004 type model, please just indicate this) | List the crack morphology parameters, and their values, that were used for these problems |
|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| COD dependent/NUREG/CR-6400 | NUREG/CR-6400 |

Quantitative Outputs

| Analysis Characteristics | | | | | | Under Normal Operational (NO) Loading | | | | Under Accident Loading (NO + SSE) | Under Normal Operational (NO) Loading | | | | Comments or Notes Pertaining to Analysis | |
|--------------------------|------------------------|---------------------|-----------------------------|------|---------------|---------------------------------------|--------------------|------------|-----------|--------------------------------------|---------------------------------------|---------------------------|-----------|------------|------------------------------------------|-----------|
| Analysis Number | Pipe Diameter (OD, mm) | Wall Thickness (mm) | Leak Rate (LR) (gpm)/(kg/s) | WRS | End Restraint | LCS @ LR (2c in. rads. or degs.) | For each LCS Crack | | | | CCS (2c in rads. or degs.) | For each unique CCS Crack | | | | |
| | | | | | | | ICOD (mm) | MWCOD (mm) | OCOD (mm) | CBM @ constant NO axial force (kN-m) | | LR (kg/s or gpm) | ICOD (mm) | MWCOD (mm) | | OCOD (mm) |
| ERPC1 | 400 | 40 | 1 (0.063) | No | Free | 62.2 deg | 0.0703 | 0.0839 | 0.0974 | 1490 | 171.2 deg | 4.3387 kg/s | 0.5978 | 0.6504 | 0.7190 | |
| ERPC2 | 400 | 40 | 1 (0.063) | No | ER1 | 88.9 deg | 0.0540 | 0.0650 | 0.0759 | 1970 | | | | | | |
| ERPC3 | 800 | 80 | 1 (0.063) | No | Free | 38.7 deg | 0.0777 | 0.0920 | 0.1063 | 14179 | 171.2 deg | 13.1135 kg/s | 1.1956 | 1.3167 | 1.4379 | |
| ERPC4 | 800 | 80 | 1 (0.063) | No | ER1 | 53.0 deg | 0.0601 | 0.0741 | 0.0880 | 17400 | | | | | | |
| ERPC5 | 150 | 12 | 1 (0.063) | No | Free | 91.2 deg | 0.0703 | 0.0814 | 0.0926 | 49 | 163.8 deg | 0.7197 kg/s | 0.3058 | 0.3296 | 0.3535 | |
| ERPC6 | 150 | 12 | 1 (0.063) | No | ER1 | 133.3 deg | 0.0549 | 0.0610 | 0.0670 | 62 | | | | | | |
| ERPC7 | 150 | 12 | 1 (0.063) | No | ER2 | 117.8 deg | 0.0595 | 0.0673 | 0.0750 | 49 | | | | | | |
| ERPC8 (Optional) | 150 | 12 | 1 (0.063) | WRS3 | ER1 | | | | | | | | | | | |

| |
|--|
| |
| |
| |

| | | | | | |
|-----------------------------|------|-------------------------|------------|-----------------|------------|
| Participating Organization: | Kiwa | Analyst Identification: | A. Shipsha | Reporting Date: | 14.02.2024 |
|-----------------------------|------|-------------------------|------------|-----------------|------------|

Codes and Procedures Used in Analysis (add space as needed)

| Name and Version # | List any code or analysis limitations for these problems (e.g., utilizes flat-plate K-solutions) | List any analysis assumptions | Briefly describe the approach that your code or analysis uses to determine output variables (e.g., COD, CBM) | Briefly describe the approach used to incorporate WRS within the evaluation | Provide any other comments related to your code capabilities or evaluation approach that affects your results |
|-------------------------|--------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| COD Code(s) | See Kiwa report regarding ERPC analyses | | | | |
| Leak Rate Code(s) | See Kiwa report regarding ERPC analyses | | | | |
| Crack Stability Code(s) | See Kiwa report regarding ERPC analyses | | | | |

Crack Morphology Modeling (add space as needed)

| Briefly describe your crack morphology model (if using a NUREG/CR-6004 type model, please just indicate this) | List the crack morphology parameters, and their values, that were used for these problems (if using NUREG/CR-6004 type model, just indicate this) |
|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| | |

Quantitative Outputs

| Analysis Characteristics | | | | | | Under Normal Operational (NO) Loading | | | | Under Accident Loading (NO + SSE) | Under Normal Operational (NO) Loading | | | | Comments or Notes Pertaining to Analysis | | |
|--------------------------|------------------------|---------------------|-----------------------------|------|---------------|---------------------------------------|--------------------|-----------------|-----------------|--------------------------------------|---------------------------------------|---------------------------|-----------|------------|------------------------------------------|----------------------------------------------------------------------------|-------------------------------------------------------|
| Analysis Number | Pipe Diameter (OD, mm) | Wall Thickness (mm) | Leak Rate (LR) (gpm)/(kg/s) | WRS | End Restraint | LCS @ LR (2c in degs.) | For each LCS Crack | | | | CCS (2c in degs.) | For each unique CCS Crack | | | | | |
| | | | | | | | ICOD (mm) | MWCOD (mm) | OCOD (mm) | CBM @ constant NO axial force (kN-m) | | LR (kg/s) | ICOD (mm) | MWCOD (mm) | | OCOD (mm) | |
| ERPC1 | 400 | 40 | 1 (0.063) | No | Free | 54.5 | 0.06882 | 0.08796 | 0.10710 | 928.9 | 128.8 | 3.087 | 0.55279 | 0.65252 | 0.75224 | Results from ISAAC/LBBPipe | |
| ERPC2 | 400 | 40 | 1 (0.063) | No | ER1 | | | | | | | | | | | Not analyzed | |
| ERPC3 | 800 | 80 | 1 (0.063) | No | Free | 35.4 | 0.07482 | 0.09384 | 0.11286 | 8033.5 | 112.5 | 5.2523 | 0.72729 | 0.87215 | 1.01700 | Results from ISAAC/LBBPipe | |
| ERPC4 | 800 | 80 | 1 (0.063) | No | ER1 | | | | | | | | | | | Not analyzed | |
| ERPC5 | 150 | 12 | 1 (0.063) | No | Free | 79.9 | 0.07272 | 0.08828 | 0.10383 | 39.8 | 140.5 | 1.487 | 0.39127 | 0.44404 | 0.49681 | Results from ISAAC/LBBPipe | |
| ERPC5_FEM | 150 | 12 | 1 (0.063) | No | Free | 82.6/82.2 | 0.07226/0.07323 | 0.08625/0.08734 | 0.10023/0.10145 | Not analyzed | 162.0 | | | | | | Results from FEM. Values are given for LE/RO analyses |
| ERPC5* | 150 | 12 | 1 (0.063) | WRS3 | Free | 85.7 | 0.09792 | 0.09132 | 0.08472 | 36.8 | 148.1/130.2* | 0.81 | 0.36877 | 0.39580 | 0.42282 | Results from ISAAC/LBBPipe. Thermal loads are treated as primary with fre | |
| ERPC6 | 150 | 12 | 1 (0.063) | No | ER1 | 120.9 | 0.05663 | 0.06489 | 0.07315 | Not analyzed | | | | | | Results from FEM. Only values from LE analyses are provided | |
| ERPC6* | 150 | 12 | 1 (0.063) | No | ER1 | 117.5 | 0.0576629 | 0.06627765 | 0.0748924 | Not analyzed | | | | | | Results from FEM. Only values from LE analyses are provided | |
| ERPC7 | 150 | 12 | 1 (0.063) | No | ER2 | 107.1 | 0.06091 | 0.07131 | 0.08171 | Not analyzed | | | | | | Results from FEM. Only values from LE analyses are provided | |
| ERPC7* | 150 | 12 | 1 (0.063) | No | ER2 | 104.7 | 0.06175 | 0.07245 | 0.08315 | Not analyzed | | | | | | Results from FEM. Only values from LE analyses are provided | |
| ERPC8* (Optional) | 150 | 12 | 1 (0.063) | WRS3 | Free | 110.7 | 0.02219 | 0.02602 | 0.02985 | 33.3 | 182/159* | 0.67 | 0.33245 | 0.34836 | 0.36427 | Results from ISAAC/LBBPipe. See report for description of this analysis. B | |

red values are averaged from ICOD and OCOD results

* analysis determined a complex crack shape with separate ID (148 for ERPC5* and 182 for ERPC8*) and OD (130 for ERPC5* and 159 for ERPC8*). Values are shown in report figure as average values.

| | | | |
|------|-------|--------------|-------------------------------------------|
| KIWA | MWCOA | 3.33559 mm*2 | ERPC5 |
| KIWA | MWCOA | 1.36220 mm*2 | ERPC8 |
| KIWA | MWCOD | 0.06371 mm | ERPC8 expected value based on ERPC5 MWCOA |

| | | | | |
|-----------------------------|-----|-----------------|---------|-------|
| Participating Organization: | NRC | Reporting Date: | Wallace | Final |
|-----------------------------|-----|-----------------|---------|-------|

Codes and Procedures Used in Analysis (add space as needed)

| | Name and Version # | List any code or analysis limitations for these problems (e.g., utilizes flat-plate K-solutions) | List any analysis assumptions | Briefly describe the approach that your code or analysis uses to determine output variables (e.g., COD, CBM) | Briefly describe the approach used to incorporate WRS within the evaluation | Provide any other comments related to your code capabilities or evaluation approach that affects your results |
|-------------------------|--------------------|--------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| COD Code(s) | | | | | | |
| Leak Rate Code(s) | | | | | | |
| Crack Stability Code(s) | | | | | | |

Crack Morphology Modeling (add space as needed)

| Briefly describe your crack morphology model (if using a NUREG/CR-6004 type model, please just indicate this) | List the crack morphology parameters, and their values, that were used for these problems (if using NUREG/CR-6004 type model, just indicate this) |
|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| | |

Quantitative Outputs

| Analysis Characteristics | | | | | | Under Normal Operational (NO) Loading | | | | Under Accident Loading (NO + SSE) | Under Normal Operational (NO) Loading | | | | Comments or Notes Pertaining to Analysis | |
|--------------------------|------------------------|---------------------|-----------------------------|------|---------------|---------------------------------------|--------------------|------------|-----------|--------------------------------------|---------------------------------------|---------------------------|-----------|------------|------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Analysis Number | Pipe Diameter (OD, mm) | Wall Thickness (mm) | Leak Rate (LR) (gpm)/(kg/s) | WRS | End Restraint | LCS @ LR (2c in rads. or degs.) | For each LCS Crack | | | | CCS (2c in rads. or degs.) | For each unique CCS Crack | | | | |
| | | | | | | | ICOD (mm) | MWCOD (mm) | OCOD (mm) | CBM @ constant NO axial force (kN-m) | | LR (kg/s or gpm) | ICOD (mm) | MWCOD (mm) | | OCOD (mm) |
| ERPC1 | 400 | 40 | 1 (0.063) | No | Free | 50.6 | 0.081 | 0.097 | 0.115 | 1736 | 183 | 12.27 | 1.784 | 1.97 | 2.155 | 2c Margin: 3.62, BM Margin: 6.11 |
| ERPC2 | 400 | 40 | 1 (0.063) | No | ER1 | 57.5 | 0.072 | 0.088 | 0.106 | 2314 | 315.5 | | | | | RC: 0.856, 2c Margin: 5.48, BM Margin: 5.33, CBM SigB = 624 MPa |
| ERPC3 | 800 | 80 | 1 (0.063) | No | Free | 31.8 | 0.088 | 0.102 | 0.123 | 14996 | 181 | 31.42 | 2.981 | 3.314 | 3.646 | 2c Margin: 5.68, BM Margin: 5.98 |
| ERPC4 | 800 | 80 | 1 (0.063) | No | ER1 | 36.3 | 0.076 | 0.094 | 0.115 | 20268 | 316.2 | | | | | RC: 0.889, 2c Margin: 8.7 BM Margin: 6.69, CBM SigB = 683 MPa |
| ERPC5 | 150 | 12 | 1 (0.063) | No | Free | 78.1 | 0.079 | 0.094 | 0.109 | 64.1 | 178 | 3.42 | 0.737 | 0.805 | 0.873 | 2c Margin: 2.29, BM Margin: 4.45 |
| ERPC6 | 150 | 12 | 1 (0.063) | No | ER1 | 93.5 | 0.069 | 0.081 | 0.094 | 82.3 | 312 | | | | | RC: 0.817, 2c Margin: 3.34, BM Margin: 4.83, CBM SigB = 495 MPa |
| ERPC7 | 150 | 12 | 1 (0.063) | No | ER2 | 91.4 | 0.07 | 0.083 | 0.096 | 72.2 | 282 | | | | | RC: 0.942, 2c Margin: 3.08, BM Margin: 4.30, CBM SigB = 440 MPa (/2) |
| ERPC8 (Optional) | 150 | 12 | 1 (0.063) | WRS3 | ER1 | 114.8 | 0.129 | 0.085 | 0.042 | 74.3 | 312 | 7.50E+07 | 2.96E+06 | 3.12E+06 | 3.25E+06 | RC: 0.714, 2c Margin: 2.72, BM Margin: 4.36, CBM SigB = 447 MPa, OD WRS Crack closure; RC@CCS = 0.017 |

RC = Restraint Coefficient
2c Margin: CCS(SSE) / LCS(NO)
BM Margin: Bmfai(LCS, 1.4xFaxSSE) / BM(SSE)

