# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Figure Title</th>
<th>Page no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 (a)</td>
<td>Flow sheet of typical pool type fast reactor</td>
<td>2</td>
</tr>
<tr>
<td>1.1 (b)</td>
<td>Vertical section of Primary circuit of typical Fast Reactor</td>
<td>3</td>
</tr>
<tr>
<td>1.2 (a)</td>
<td>Fuel Subassembly of a medium size fast breeder reactor</td>
<td>5</td>
</tr>
<tr>
<td>1.2 (b)</td>
<td>Terminology and different types of sub-channels in a subassembly</td>
<td>6</td>
</tr>
<tr>
<td>3.1 (a)</td>
<td>Cross stream structured mesh for a 7 pin bundle</td>
<td>25</td>
</tr>
<tr>
<td>3.1 (b)</td>
<td>Isometric view of mesh pattern of 7 pin bundle</td>
<td>25</td>
</tr>
<tr>
<td>3.1 (c)</td>
<td>Structured mesh over the pins and helical wire</td>
<td>26</td>
</tr>
<tr>
<td>3.1 (d)</td>
<td>Mesh pattern in the vicinity of wire and pin in helical wire wrapped pin bundle</td>
<td>26</td>
</tr>
<tr>
<td>3.1 (e)</td>
<td>Cross stream structured mesh for a 217 pin bundle</td>
<td>27</td>
</tr>
<tr>
<td>3.1 (f)</td>
<td>Mesh pattern of 1/6th pitch of a 217 pin bundle</td>
<td>27</td>
</tr>
<tr>
<td>3.2</td>
<td>Boundary conditions for the thermal hydraulic analysis of the 217 pin fuel bundle</td>
<td>32</td>
</tr>
<tr>
<td>3.3 (a)</td>
<td>Finite volume mesh of fuel pellet, clad and wire</td>
<td>36</td>
</tr>
<tr>
<td>3.3 (b)</td>
<td>Temperature distribution in the fuel pellet, clad and wire assembly</td>
<td>36</td>
</tr>
<tr>
<td>3.4 (a)</td>
<td>Prediction of friction factor for 7 pin bundle with different turbulence models for Re = 100000</td>
<td>39</td>
</tr>
<tr>
<td>3.4 (b)</td>
<td>Prediction of Nusselt number for 7 pin bundle with different turbulence models for Re = 100000</td>
<td>39</td>
</tr>
<tr>
<td>3.5 (a)</td>
<td>Pressure drop of pin bundle with various number points on pin and wire</td>
<td>40</td>
</tr>
<tr>
<td>3.5 (b)</td>
<td>Area averaged clad temperature at the exit of the pin bundle with various number points on pin and wire</td>
<td>41</td>
</tr>
<tr>
<td>3.6 (a)</td>
<td>Comparison of friction factor of 217 pin bundle with experimental data and Chen et al (2014) correlation</td>
<td>42</td>
</tr>
<tr>
<td>3.6 (b)</td>
<td>Comparison of Nusselt number at the exit of 217 pin bundle with experimental correlation</td>
<td>43</td>
</tr>
<tr>
<td>3.6 (c)</td>
<td>Comparison of Nusselt number at the exit of 217 pin bundle with experimental correlation for water flow through the</td>
<td>44</td>
</tr>
</tbody>
</table>
bundle.

4.1 (a) Transverse velocity field at 33 mm from the inlet of helical wire wrap 7 pin bundle

4.1 (b) Transverse velocity field at 66 mm from the inlet of helical wire wrap 7 pin bundle

4.1 (c) Transverse velocity field at the 99 mm from the inlet of helical wire wrap 7 pin bundle

4.1 (d) Transverse velocity field at the 133 mm from the inlet of helical wire wrap 7 pin bundle

4.1 (e) Transverse velocity field at the 166 mm from the inlet of helical wire wrap 7 pin bundle

4.1 (f) Transverse velocity field at the exit of helical wire wrapped 7 pin bundle

4.1 (g) Close-up view of transverse velocity field at the exit of helical wire wrap 7 pin bundle in X – Y plane

4.2 (a) Variation of transverse velocity with helical pitch of the spacer wire.

4.2 (b) Variation of rolling up angle with helical pitch of the spacer wire

4.3 (a) Axial velocity field at 33 mm from the inlet of helical wire wrapped 7 pin bundle

4.3 (b) Axial velocity field at 66 mm from the inlet of helical wire wrap 7 pin bundle

4.3 (c) Axial velocity field at 99 mm from the inlet of helical wire wrap 7 pin bundle

4.3 (d) Axial velocity field at 133 mm from the inlet of helical wire wrap 7 pin bundle

4.3 (e) Axial velocity field at 166 mm from the inlet of helical wire wrap 7 pin bundle

4.3 (f) Axial velocity field at exit of helical wire wrap 7 pin bundle

4.4 (a) Transverse velocity field in straight wire wrap 7 pin bundle
4.4 (b) Transverse velocity field in straight wire wrap 7 pin bundle

4.5 (a) Comparison of friction factor of 7 pin bundle with Chen et al. (2014) correlation

4.5 (b) Comparison of friction factor of helical and straight wire pin bundle with Blasius correlation

4.5 (c) Variation of friction factor with helical pitch length for 7 pin bundle

4.6 (a) Temperature field at 33 mm from the inlet of helical wire wrap 7 pin bundle

4.6 (b) Temperature field at 66 mm from the inlet of helical wire wrap 7 pin bundle

4.6 (c) Temperature field at 99 mm from the inlet of helical wire wrap 7 pin bundle

4.6 (d) Temperature field at 133 mm from the inlet of helical wire wrap 7 pin bundle

4.6 (e) Temperature field at 166 mm from the inlet of helical wire wrap 7 pin bundle

4.6 (f) Temperature field at the exit of helical wire wrap 7 pin bundle

4.7 (a) Temperature field at the exit of straight wire 7 pin bundle

4.7 (b) Temperature field at the exit of helical wire 7 pin bundle

4.8 Comparison of Nusselt number at the bundle exit of helical and straight wire 7 pin bundle with experimental correlation

5.1 (a) Transverse velocity field at the exit of helical wire wrap 19 pin bundle

5.1 (b) Close-up view of transverse velocity field at the exit of helical wire wrap 19 pin bundle in X – Y plane

5.1 (c) Transverse velocity field at the exit of helical wire wrap 37 pin bundle

5.1 (d) Close-up view of transverse velocity field at the exit of helical wire wrap 37 pin bundle in X – Y plane
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 (e)</td>
<td>Transverse velocity field at the exit of helical wire wrap 91 pin bundle</td>
</tr>
<tr>
<td>5.1 (f)</td>
<td>Close-up view of transverse velocity field at the exit of helical wire wrap 91 pin bundle in X – Y plane</td>
</tr>
<tr>
<td>5.1 (g)</td>
<td>Variation of transverse velocity with number of pins in the bundle</td>
</tr>
<tr>
<td>5.1 (h)</td>
<td>Variation of equivalent diameter with number of pins in the bundle</td>
</tr>
<tr>
<td>5.1 (i)</td>
<td>Variation of inlet axial velocity with number of pins in the bundle</td>
</tr>
<tr>
<td>5.1 (j)</td>
<td>Variation of ratio of axial velocity to transverse velocity with number of pins in the bundle</td>
</tr>
<tr>
<td>5.2 (a)</td>
<td>Axial velocity field at the exit of helical wire wrap 19 pin bundle indicating the values of normalized velocity at the central and peripheral sub channels</td>
</tr>
<tr>
<td>5.2 (b)</td>
<td>Axial velocity field at the exit of helical wire wrap 37 pin bundle indicating the values of normalized velocity at the central and peripheral sub channels</td>
</tr>
<tr>
<td>5.2 (c)</td>
<td>Axial velocity field at the exit of helical wire wrap 91 pin bundle indicating the values of normalized velocity at the central and peripheral sub channels</td>
</tr>
<tr>
<td>5.2 (d)</td>
<td>Experimental axial velocity field at the exit of helical wire wrap 91 pin bundle indicating the values of normalized velocity at the central and peripheral sub channels</td>
</tr>
<tr>
<td>5.3</td>
<td>Comparison of friction factor of various pin bundles with Chen et al (2014) correlation</td>
</tr>
<tr>
<td>5.4 (a)</td>
<td>Temperature field at the exit of helical wire wrap 19 pin bundle</td>
</tr>
<tr>
<td>5.4 (b)</td>
<td>Temperature field at the exit of helical wire wrap 37 pin bundle</td>
</tr>
<tr>
<td>5.4 (c)</td>
<td>Temperature field at the exit of helical wire wrap 91 pin bundle</td>
</tr>
<tr>
<td>5.5 (a)</td>
<td>Comparison of Nusselt number for various pin bundles with Kazimi and Carelli correlation (1980)</td>
</tr>
</tbody>
</table>
5.5 (b) Variation of Nusselt number with number of pins for Re = 100,000

6.1 (a) The transverse velocity field at the exit of straight wire wrap 217 pin bundle

6.1 (b) The transverse velocity field at the exit of helical wire wrap 217 pin bundle

6.1 (c) Close-up view of transverse velocity field at the exit of helical wire wrap 217 pin bundle in X – Y plane

6.1 (d) The axial velocity field at the exit of straight wire wrap 217 pin bundle

6.1 (e) The axial velocity field at the exit of helical wire wrap 217 pin bundle

6.2 (a) The temperature field at the exit of straight wire 217 pin bundle (200 mm from the inlet)

6.2 (b) The temperature field at the exit of helical wire 217 pin bundle (200 mm from the inlet)

6.3 Comparison of friction factor of 217 pin bundle with experimental data and Chen et al correlation (2014)

6.4 (a) The transverse velocity field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 100000

6.4 (b) The transverse velocity field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 50000

6.4 (c) The transverse velocity field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 25000

6.4 (d) The transverse velocity field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 10000

6.4 (e) The transverse velocity field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 2500

6.4 (f) Variation of transverse velocity at the outlet of 217 pin bundle with Reynolds number

6.5 (a) The temperature field at 33 mm from the inlet of helical wire wrap 217 bundle

6.5 (b) The temperature field at 66 mm from the inlet of helical wire wrap 217 bundle

6.5 (c) The temperature field at 99 mm from the inlet of helical wire wrap 217 bundle
6.5 (d) The temperature field at 133 mm from the inlet of helical wire wrap 217 bundle
6.5 (e) The temperature field at 166 mm from the inlet of helical wire wrap 217 bundle
6.5 (f) The temperature field at the exit of helical wire wrap 217 bundle
6.6 (a) The temperature field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 95,000
6.6 (b) The temperature field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 50000
6.6 (c) The temperature field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 25000
6.6 (d) The temperature field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 10000
6.6 (e) The temperature field at the exit of helical wire wrap 217 pin bundle for Reynolds number = 2500
6.7 Comparison of Nusselt number at the exit of 217 pin bundle with experimental correlation
6.8 (a) The transverse velocity field at the exit of 1000 mm length of helical wire 217 pin bundle
6.8 (b) Close-up view of transverse velocity field at the exit of 1000 mm length of helical wire 217 pin bundle in X – Y plane
6.9 The axial velocity distribution at the exit of 1000 mm length of the bundle
6.10 (a) The temperature field at 200 mm from the inlet of helical wire wrap 217 pin bundle
6.10 (b) The temperature field at 400 mm from the inlet of helical wire wrap 217 pin bundle
6.10 (c) The temperature field at 600 mm from the inlet of helical wire wrap 217 pin bundle
6.10 (d) The temperature field at 800 mm from the inlet of helical wire wrap 217 pin bundle
6.10 (e) The temperature field at the exit (1000 mm) of helical wire
Development of Nusselt number along the length of 217 pin bundle

The transverse velocity field at the exit of 100 mm helical pitch wire wrap 217 pin bundle

Close-up view of the transverse velocity field at exit of 100 mm helical pitch wire wrap 217 pin bundle in X – Y plane

The transverse velocity field at the exit of 200 mm helical pitch wire wrap 217 pin bundle

Close-up view of the transverse velocity field at exit of 200 mm helical pitch wire wrap 217 pin bundle in X – Y plane

The transverse velocity field at the exit of 300 mm helical pitch wire wrap 217 pin bundle

Close-up view of the transverse velocity field at exit of 300 mm helical pitch wire wrap 217 pin bundle in X – Y plane

The transverse velocity field at the bundle exit of 1.25 mm diameter helical wire wrap 217 pin bundle

Close-up view of transverse velocity field at the bundle exit of 1.25 mm diameter helical wire wrap 217 pin bundle

The transverse velocity field at the bundle exit of 1.65 mm diameter helical wire wrap 217 pin bundle

Close-up view of the transverse velocity field at the bundle exit of 1.65 mm diameter helical wire wrap 217 pin bundle

The transverse velocity field at the bundle exit of 2.0 mm diameter helical wire wrap 217 pin bundle

Close-up view of transverse velocity field at the bundle exit of 2.0 mm diameter helical wire wrap 217 pin bundle

The axial velocity field at the bundle exit of 100 mm helical pitch wire wrap 217 pin bundle
7.3 (b) The axial velocity field at the bundle exit of 200 mm helical pitch wire wrap 217 pin bundle
7.3 (c) The axial velocity field at the bundle exit of 300 mm helical pitch wire wrap 217 pin bundle
7.4 (a) The axial velocity field at the bundle exit of 1.25 mm diameter helical wire wrap 217 pin bundle
7.4 (b) The axial velocity field at the bundle exit of 1.65 mm diameter helical wire wrap 217 pin bundle
7.4 (c) The axial velocity field at the bundle exit of 2.0 mm diameter helical wire wrap 217 pin bundle
7.5 (a) Variation of friction factor of 217 pin bundle with helical pitch
7.5 (b) Dependence of friction factor of 217 bundle on helical pitch for various Reynolds number
7.6 Dependence of friction factor of 217 bundle on helical wire diameter for various Reynolds number
7.7 (a) Temperature field at 100 mm elevation for 100 mm helical pitch wire wrap 217 pin bundle
7.7 (b) Temperature field at 100 mm elevation for 200 mm helical pitch wire wrap 217 pin bundle
7.7(c) Temperature field at 100 mm elevation for 300 mm helical pitch wire wrap 217 pin bundle
7.8 (a) Temperature field at the exit of for 1.25 mm diameter helical wire wrap 217 pin bundle
7.8 (b) Temperature field at the exit of for 1.65 mm diameter helical wire wrap 217 pin bundle
7.8 (c) Temperature field at the exit of for 2.0 mm diameter helical wire wrap 217 pin bundle
7.9 Comparison of Nusselt number at 100 mm from the inlet of 217 fuel pin bundle for various helical pitch
7.10 Comparison of Nusselt number at the exit of 217 fuel pin bundle for various helical wire diameter
8.1 (a) Pin numbering of the 217 pin bundle and angular locations of the sub-channels of various hexagonal rows.
8.1 (b) Definition of angle along the circumference of the pin
8.2 (a) Clad temperature distribution around the central and peripheral pins at 200 mm from the inlet
8.2 (b) Clad temperature distribution around the central and peripheral pins at the outlet (1000 mm from the inlet)
8.3 (a) Sodium temperature distribution at 200 mm from the inlet of 217 pin bundle
8.3 (b) Sodium temperature distribution at 1000 mm from the inlet of 217 pin bundle
8.4.1 (a) Clad temperature around the central pin for different helical pitches
8.4.1 (b) Clad temperature around the pin no. 145 located at the 7th row for different helical pitches
8.4.1 (c) Clad temperature around the pin no. 152 located at the 7th row for different helical pitches
8.4.1 (d) Clad temperature around the pin no. 160 located at the 7th row for different helical pitches
8.4.1 (e) Clad temperature around the pin no. 166 located at the 7th row for different helical pitches
8.4.1 (f) Clad temperature around the pin no. 131 located at the 7th row for different helical pitches
8.4.1 (g) Clad temperature around the pin no. 217 located at the peripheral row for different helical pitches
8.4.2 (a) Clad temperature around the central pin for different wire diameters
8.4.2 (b) Clad temperature around the pin no. 145 located at the 7th row for different wire diameters
8.4.2 (c) Clad temperature around the pin no. 217 located at the peripheral row for different wire diameters
8.5.1 (a) Sodium temperature at 100 mm elevation of 217 pin bundle: helical pitch = 100 mm
8.5.1 (b) Sodium temperature at 100 mm elevation of 217 pin bundle: helical pitch = 200 mm
8.5.1 (c) Sodium temperature at 100 mm elevation of 217 pin bundle: helical pitch = 300 mm
8.5.2 (a) Sodium temperature distribution at the outlet of 217 pin bundle: Helical wire diameter = 1.25 mm
8.5.2 (b) Sodium temperature distribution at the outlet of 217 pin bundle: Helical wire diameter = 1.65 mm
8.5.2 (c) Sodium temperature distribution at the outlet of 217 pin bundle: Helical wire diameter = 2.0 mm
9.1 (a) Variation of hotspot factor with number of pins
9.1 (b) Variation of hotspot factor with length of the bundle of 1000 mm
9.1 (c) Variation of Nusselt number with length of the bundle
9.1 (d) Variation of hotspot factor with helical pitch of the wire
9.2 (a) Variation of hotchannel factor with number of pins
9.2 (b) Variation of hotchannel factor with length of the bundle
9.2 (c) Variation of hotchannel factor with helical pitch of the wire
10.1 Variation of mean sodium velocity in central and peripheral sub-channels at the outlet of the bundle with number of pins
10.2 Variation of sodium temperature in central and peripheral sub-channels at the outlet of the bundle with number of pins
10.3 Variation of temperature difference between central and peripheral sub-channels at the outlet of the bundle with number of pins
10.4 Comparison of CFD predicted sodium temperatures in central and peripheral sub-channels with that of the calculated using extendibility procedure
10.5 Variation of temperature difference between the mean temperatures of central and peripheral sub-channels of the bundle of 1000 mm.