Bearing and Brake Temperature Alarm Models

Version 1.0

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Document history

<table>
<thead>
<tr>
<th>Version</th>
<th>Summary of changes</th>
</tr>
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<tbody>
<tr>
<td>1.0</td>
<td>First issue</td>
</tr>
</tbody>
</table>

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Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the ASA Charter, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW's governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW’s process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW’s Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole of life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

This standard provides wheel bearing and brake temperature alarm models for the bearing brake temperature wayside systems operating in the metropolitan rail area.

This standard has been developed by the ASA in conjunction with Sydney Trains and approved by the ASA Configuration Control Board.
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1. Introduction

Bearing and brake temperature (BBT) trackside systems include hot bearing detectors (HBD), hot wheel detectors (HWD) incorporating cold wheel detectors (CWD), dragging equipment detectors (DED), wheel sensors, automatic equipment identification (AEI) readers and trackside equipment including junction boxes and other hardware.

Wheel sensors and AEI readers are used together to identify each vehicle, axles on each vehicle, train’s speed and train’s direction of a consist passing a site.

HBD sub-systems measure all bearing temperatures as a consist passes a site. The HWD sub-system measures all wheel and brake disc (wheel mounted and axle mounted) temperatures across the full wheel or brake disc.

The DED detects any equipment hanging below the train’s kinematic envelope.

Systems raise alarms to the designated signal boxes or signal panels indicating the defects on passing trains such as high temperatures in bearings, brakes or wheels and dragging equipment. Alarms are also communicated to drivers via radio.

As of 2013, there are two generations of BBT systems from different vendors installed in the metropolitan rail area. The 2nd generation BBT systems are Australian VEIC Technology (AVT) Rail Systems (installed in 2005) and the 3rd generation BBT systems are SST (now Voestalpine VAE Railway Systems) installed in 2012.

Each of the different generation systems were supplied by different vendors and their proposed alarm models and thresholds were different which could lead to inconsistencies in the alarms triggered. For example, a high level alarm generated by one system may have been equivalent to a medium level alarm generated by another system.

The objective is to have a standard set of alarm and alert models and thresholds defined for all the BBT systems installed on the metropolitan rail area. This results in a consistent approach to HBD, HWD and CWD alarm and alert definitions which are independent of the system producing them.

2. Purpose

This standard defines the HBD, HWD and CWD alarm and alert models and thresholds settings for all BBT systems in the metropolitan rail area. The information is crucial to BBT system vendors, rolling stock operators and BBT trackside system users and maintainers.

This standard allows BBT system vendors to provide equipment with the required alarm and alert models and thresholds to ensure the operation of all BBT trackside systems is consistent within the metropolitan rail area.
This standard informs rolling stock operators about BBT trackside systems used to monitor all rolling stock in the metropolitan rail area as required in TS TOC.1 Train Operating Conditions (TOC) Manual – General Instructions.

2.1. Scope

This document defines the standard BBT monitoring system alarm and alert models and thresholds for rolling stock bearings and brakes or wheels. The models are to be used by all BBT monitoring systems, where installed, in the metropolitan rail area and the Country Regional Network.

2.2. Application

This standard applies to all configurable BBT trackside systems.

3. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

Transport for NSW standards

TS TOC.1 Train Operating Conditions (TOC) Manual – General Instructions

4. Terms and definitions

The following terms and definitions apply in this document:

AEI automatic equipment identification

alarm notification that a condition exceeds predetermined HBD, HWD or DED system parameters that requires immediate attention from the local signaller. Alarm notifications primarily occur as a pop up and audible tone in the SCADA system

alert notification that a condition exceeds predetermined HBD, HWD or DED system parameters that may not require immediate attention. Alerts will normally be distributed by email to rolling stock engineers and maintainers.

BBT bearing and brake temperature

BC brake cut-out

CWD cold wheel detector

consist rolling stock such as vehicles, units, cars, wagons, sets and locomotives marshalled together operating as a train set

DED dragging equipment detector
DR deceleration rate

E1 alarm and alert model exception 1

E2 alarm and alert model exception 2

HBD hot bearing detector

HWD hot wheel detector

locomotive dedicated motive power unit primarily used to haul other rail vehicles including freight, wagons or locomotive hauled passenger trailer cars

metropolitan rail area the rail freight network and the rail passenger network within the metropolitan rail area bounded by Newcastle (in the north), Richmond (in the northwest), Bowenfels (in the west), Macarthur (in the southwest) and Bomaderry (in the south), and all connection lines and sidings within these areas, but excluding private sidings

The symbols in Table 1 are used in the algorithms in this document.

### Table 1 - Algorithm symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>Cold wheel algorithm temperature gradient factor</td>
</tr>
<tr>
<td>C_{AV}</td>
<td>Average temperature rise of all the relative HWD maximum (rim and hub) temperature from vehicles of the same vehicle description per consist. Wheel temperatures that have exceeded the low HWD alarm threshold (that is triggered a low, medium or high HWD alarm) are excluded from this average.</td>
</tr>
<tr>
<td>CWT1</td>
<td>Cold wheel threshold number 1 that applies to the corresponding vehicles for cold wheel alert algorithm 1</td>
</tr>
<tr>
<td>CWT2</td>
<td>Cold wheel threshold number 2 that applies to the corresponding vehicles for cold wheel alert algorithm 2</td>
</tr>
<tr>
<td>CWT3</td>
<td>Cold wheel threshold number 3 that applies to the corresponding vehicles for cold wheel alert algorithm 2</td>
</tr>
<tr>
<td>E1_{AW}</td>
<td>E1 absolute wheel temperature threshold</td>
</tr>
<tr>
<td>N_C</td>
<td>Total number of passenger carriages in the train</td>
</tr>
<tr>
<td>N_{CC}</td>
<td>Number of passenger carriages with all wheels triggering cold wheel alerts</td>
</tr>
<tr>
<td>N_{CW}</td>
<td>Number of wagons with all wheels triggering cold wheel alerts</td>
</tr>
<tr>
<td>N_W</td>
<td>Total number of wagons in the train (that is, total freight vehicles excluding locomotives)</td>
</tr>
<tr>
<td>S_{AB}</td>
<td>Bearing alarm absolute temperature threshold</td>
</tr>
<tr>
<td>S_{ABH}</td>
<td>Alarm or alert hot bearing temperature threshold</td>
</tr>
<tr>
<td>S_{ABW}</td>
<td>Alarm or alert warm bearing temperature threshold</td>
</tr>
<tr>
<td>S_{ADB}</td>
<td>Bearing alarm or alert axle differential temperature threshold</td>
</tr>
<tr>
<td>S_{AW}</td>
<td>Wheel alarm absolute temperature threshold</td>
</tr>
<tr>
<td>S_{HIGH}</td>
<td>High ambient temperature setting marking the end of the ambient temperature compensation zone</td>
</tr>
</tbody>
</table>
5. Bearing alarms and alerts

High bearing temperatures indicate the presence of bearing defects or vehicle overloading which can lead to bearing failure and possible derailment.

Section 5.1 to Section 5.6 describes the bearing alarm and alert models and thresholds for identifying abnormal bearing operating temperatures.

Appendix A describes the third generation SST Phoenix site specific thresholds.

5.1. Bearing alarm and alert levels

The following levels of bearing alarms or alerts shall always be used:

- hot bearing alarms
- warm bearing alarms
- low bearing alerts

5.2. Model groups

The HBD system shall have two types of bearing alarm or alert model groups as follows:

- passenger bearing alarm or alert model group P1, P2 and P3
- freight and other bearing alarm or alert model group F1, F2 and F3
Measured bearing temperatures for each train pass shall be checked against the designated alarm or alert model group for the train type. For example, detected bearing temperatures of passenger trains shall be checked against the passenger bearing alarm or alert model group P1, P2 or P3 and the detected bearing temperatures from freight and other unidentified trains shall be checked against the bearing alarm or alert model group F1, F2 or F3.

Note: Alarm or alert models P2 and P3 for passenger trains and alarm or alert models F2 and F3 for freight trains use the same algorithms but are separated to allow the user to set different thresholds for the two types.

Note: Algorithm F1 for freight trains uses ambient temperature compensation for warm bearing alarms while algorithm P1 for passenger trains does not.

After each pass of a train the system checks the bearing temperature using the alarm or alert model groups and shall display the highest level of alarm or alert detected. For example, if a passenger train bearing temperature triggers a warm bearing alarm according to model P1 and a hot bearing alarm according to model P2, the system shall display a hot bearing alarm.

All systems shall allow the user to identify which alarm or alert model was triggered.

5.3. Temperature measurements and calculations

Section 5.3.1 to Section 5.3.4 to provide specific requirements for the measurement and calculations of the temperatures used in bearing alarms and alerts

5.3.1. Absolute bearing temperature (T\text{AB})

The absolute bearing temperature is the maximum absolute temperature value of each bearing measured by the HBD system. The vendor shall explain and document how this value is calculated for TfNSW’s review.

5.3.2. Average absolute bearing temperature (T\text{AAB})

The average absolute bearing temperature (T\text{AAB}) is the average absolute temperature of all the bearings on the same vehicle as the single bearing being checked. The vendor shall explain and document how this value is calculated for TfNSW’s review.

5.3.3. Absolute bearing temperature adjacent (T\text{ABA})

The absolute bearing temperature adjacent (T\text{ABA}) is the absolute temperature of the adjacent bearing on the same axle to the single bearing being checked. The vendor shall explain and document how this value is calculated for TfNSW’s review.
5.3.4. **Ambient temperature (T\textsubscript{AMB})**

The ambient temperature used in the alarm model calculations shall be obtained from the temperature sensor located near the trackside hut.

Any other methods inclusive or exclusive of the trackside hut ambient temperature sensor used for calculating the ambient temperature can be suggested by the HWD vendor for review by TfNSW.

5.4. **Thresholds**

It is preferable for the alarm or alert thresholds to be dependent on the vehicle class detected using the AEI tag readers. If the system can achieve this, then the thresholds for each of the vehicle classes shall be user configurable. In addition, there shall be no need for separate freight and passenger alarm or alert models as the vehicle class is sufficient to differentiate between the two types.

The default threshold values specified in Table 2 to Table 7 shall be the values used for all vehicle classes, AEI tag detected or not.

Alarm model thresholds shall conform to the values specified in this standard whereas alert model thresholds are only recommendations and can be configured as required by the responsible rolling stock owner, operator or maintainer.

5.5. **Passenger bearing alarm or alert models**

Sections 5.5.1 to Section 5.5.3 define the bearing alarm or alert models for passenger trains.

5.5.1. **Model P1**

Model P1 shall have a configurable bearing alarm absolute temperature threshold (S\textsubscript{AB}). The model shall compare each maximum absolute bearing temperature value of each bearing measured by the HBD system (T\textsubscript{AB}) against the user defined threshold (S\textsubscript{AB}). The alarm is triggered when the absolute temperature of a bearing is greater than or equal to the defined threshold. The P1 model shall only produce hot and warm bearing alarms.

**Alarm or alert condition:**

The alarm or alert model shall trigger alarms or alerts when the condition below is satisfied.

\[ T_{AB} \geq S_{AB} \]
Where:

\[ T_{AB} = \text{maximum absolute temperature value of each bearing measured by the HBD system} \]

\[ S_{AB} = \text{alarm or alert absolute temperature threshold (user configurable)} \]

Default thresholds:

Table 2 shows the default thresholds for model P1 alarms and alerts.

**Table 2 – Model P1 thresholds**

<table>
<thead>
<tr>
<th>Alarm or alert level</th>
<th>( S_{AB} ) (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot bearing alarm</td>
<td>100</td>
</tr>
<tr>
<td>Warm bearing alarm</td>
<td>90</td>
</tr>
<tr>
<td>Low bearing alert</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

Appendix B contains a graphical representation of the combined P1 and P2 alarm or alert models.

### 5.5.2. Model P2

Model P2 shall have a configurable bearing alarm or alert vehicle differential temperature threshold (\( S_{VDB} \)). The model shall compare each \( T_{AB} \) against the sum of the user defined \( S_{VDB} \) and the average absolute bearing temperature of all the bearings on the same vehicle as the single bearing being checked \( (T_{AAB}) \). The alarm is triggered when the absolute temperature of a bearing is greater than or equal to the total of \( T_{AAB} \) plus \( S_{VDB} \). The model shall produce only low bearing alerts and warm bearing alarms.

Alarm or alert condition:

The alarm or alert model shall trigger alarms or alerts when the condition below is satisfied.

\[ T_{AB} \geq (T_{AAB} + S_{VDB}) \]

Where:

\[ T_{AB} = \text{is the absolute temperature of a single bearing} \]

\[ S_{VDB} = \text{bearing alarm or alert vehicle differential temperature threshold (user configurable)} \]

\[ T_{AAB} = \text{average absolute temperature of all the bearings on the same vehicle as the single bearing being checked} \]

Default thresholds:

Table 3 shows the default thresholds for P2 alarms and alerts.
Table 3 – Model P2 thresholds

<table>
<thead>
<tr>
<th>Alarm or alert level</th>
<th>$S_{VDB}$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm bearing alarm</td>
<td>50</td>
</tr>
<tr>
<td>Low bearing alert</td>
<td>30</td>
</tr>
</tbody>
</table>

Appendix B contains a graphical representation of the combined P1 and P2 alarm or alert models.

5.5.3. Model P3

Model P3 shall have a configurable bearing alarm or alert axle differential temperature threshold ($S_{ADB}$). The model shall compare each absolute bearing temperature ($T_{AB}$) against the sum of the user defined threshold ($S_{ADB}$) and the absolute temperature of the adjacent bearing on the same axle as the single bearing being checked ($T_{ABA}$). The alarm is triggered when the absolute temperature of a bearing is greater than or equal to the total of ($T_{ABA} + S_{ADB}$). The model shall produce only low bearing alerts.

The risk of false alerts due to the effect of the sun on one side of the train shall also be catered for by this model. If more than low alerts (which shall be an administrator configurable parameter) are activated by model P3 they shall be displayed within the database and not distributed as emails. They shall be ignored for statistical analysis of alarm or alerts.

Where a cold wheel alert is triggered, model P3 shall be disabled from triggering on the same axle to prevent false alerts.

Alarm or alert condition:

The alarm or alert model shall trigger alarms or alerts when the condition below is satisfied.

$$T_{AB} \geq (T_{ABA} + S_{ADB})$$

Where:

- $T_{AB}$ = maximum absolute temperature value of each bearing measured by the HBD system
- $S_{ADB}$ = bearing alarm or alert axle differential temperature threshold (user configurable)
- $T_{ABA}$ = absolute temperature of the adjacent bearing on the same axle as the single bearing being checked

Default thresholds: Table 4 shows the recommended default thresholds for model P3 alarms or alerts.
5.6. **Freight and other bearing alarm or alert models**

Section 5.6.1 to Section 5.6.3 define the bearing alarm or alert models for freight and other trains.

5.6.1. **Model F1**

Model F1 shall use ambient temperature compensation for warm alarms when the ambient temperature is within a configurable range between the low ambient temperature setting marking the start of the ambient temperature compensation zone (S\textsubscript{LOW}) and the high ambient temperature setting marking the end of the ambient temperature compensation zone (S\textsubscript{HIGH}).

Model F1 shall use configurable absolute temperature threshold settings for the warm bearing temperature threshold (S\textsubscript{ABW}) and the hot bearing temperature threshold (S\textsubscript{ABH}) respectively.

The model shall compare each measured absolute bearing temperature (T\textsubscript{AB}) against the following conditions to produce the hot and warm bearing alarms only.

**Alarm or alert condition:**

- The alarm or alert model shall trigger a hot bearing alarm or alert when the following condition (condition 1) is satisfied.

\[
T_{AB} \geq S_{ABH}
\]

- The alarm or alert model shall trigger a warm bearing alarm or alert when the following conditions (condition 2 and 3) are satisfied.

\[
T_{AB} \geq S_{ABW} \text{ AND } T_{AMB} \leq S_{LOW}
\]

or

\[
T_{AB} \geq S_{ABW} \text{ AND } T_{AB} \geq m \times T_{AMB} + c
\]

Where:

\[
m = \frac{S_{ABH} - S_{ABW}}{S_{HIGH} - S_{LOW}}
\]

\[
c = S_{ABW} - \frac{S_{ABH} - S_{ABW}}{S_{HIGH} - S_{LOW}} \times S_{LOW}
\]

T\textsubscript{AB} = maximum absolute temperature value of each bearing measured by the HBD system

T\textsubscript{AMB} = ambient temperature

---

**Table 4 – Model P3 thresholds**

<table>
<thead>
<tr>
<th>Alarm or alert level</th>
<th>S\textsubscript{ADB} (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low bearing alert</td>
<td>15</td>
</tr>
</tbody>
</table>
S_{ABH} = \text{alarm or alert hot bearing temperature threshold (user configurable)}

S_{ABW} = \text{alarm or alert warm bearing temperature threshold (user configurable)}

S_{LOW} = \text{low ambient temperature setting marking the start of the ambient temperature compensation zone (user configurable)}

S_{HIGH} = \text{high ambient temperature setting marking the end of the ambient temperature compensation zone (user configurable)}

Default thresholds:

Table 5 shows the default settings for model F1 alarms or alerts.

<table>
<thead>
<tr>
<th>Parameter (°C)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_{ABH} 100</td>
<td>Hot bearing alarm</td>
</tr>
<tr>
<td>S_{ABW} 90</td>
<td>Warm bearing alarm</td>
</tr>
<tr>
<td>S_{LOW} 20</td>
<td>Low ambient temperature setting</td>
</tr>
<tr>
<td>S_{HIGH} 30</td>
<td>High ambient temperature setting</td>
</tr>
</tbody>
</table>

Figure 2 in Appendix B contains a graphical representation of the F1 alarm or alert models.

5.6.2. **Model F2**

Model F2 shall have a configurable vehicle differential temperature threshold (S_{VDB}). The model shall compare each absolute bearing temperature (T_{AB}) against the sum of the user defined threshold (S_{VDB}) and the average absolute bearing temperature (T_{AAB}). The alarm is triggered when the absolute temperature of a bearing is greater than or equal to the total of (T_{AAB} + S_{VDB}). The model shall produce only low bearing alerts and warm bearing alarms.

**Alarm or alert condition:**

The alarm or alert model shall trigger alarms or alerts when the condition below is satisfied.

\[ T_{AB} \geq (T_{AAB} + S_{VDB}) \]

Where:

\[ T_{AB} = \text{maximum absolute temperature value of each bearing measured by the HBD system} \]

\[ S_{VDB} = \text{alarm or alert vehicle differential temperature threshold (user configurable)} \]

\[ T_{AAB} = \text{average absolute temperature of all the bearings on the same vehicle as the single bearing being checked} \]
Default thresholds:

Table 6 shows the default thresholds for model F2 alarms or alerts.

<table>
<thead>
<tr>
<th>Alarm or alert level</th>
<th>$S_{VDB}$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm bearing alarm</td>
<td>50</td>
</tr>
<tr>
<td>Low bearing alert</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 6 – Model F2 thresholds

Figure 1 in Appendix B contains a graphical representation of the HBD alarm or alert model F2.

5.6.3. Model F3

Model F3 shall have a configurable axle differential temperature threshold ($S_{ADB}$). The model shall compare each absolute bearing temperature ($T_{AB}$) against the sum of the user defined threshold ($S_{ADB}$) and the absolute bearing temperature adjacent ($T_{ABA}$). The alarm is triggered when the absolute temperature of a bearing is greater than or equal to the total of ($T_{ABA} + S_{ADB}$).

The model shall produce only low bearing alerts.

The risk of false alerts due to the effect of the sun on one side of the train shall also be catered for by this model. If more than low alerts (which shall be an administrator configurable parameter) are activated by model F3 they shall be displayed within the database and not distributed as emails. They shall be ignored for statistical analysis of alarm or alerts.

Where a cold wheel alert is triggered, model F3 shall be disabled from triggering on the same axle to prevent false alerts.

Alarm or alert condition:

The alarm or alert model shall trigger alarms/alerts when the condition below is satisfied.

$$T_{AB} \geq (T_{ABA} + S_{ADB})$$

Where:

- $T_{AB}$ = maximum absolute temperature value of each bearing measured by the HBD system
- $S_{ADB}$ = alarm or alert axle differential temperature threshold (user configurable)
- $T_{ABA}$ = absolute temperature of the adjacent bearing on the same axle as the single bearing being checked

Default thresholds:

Table 7 shows the recommended default thresholds for model F3 alarms or alerts.
6. Wheel alarms and alerts

High wheel temperatures can indicate a brake fault or prolonged brake application which can be caused by brake system fault or failure, stiff or incorrectly adjusted rigging or inadvertently applied park brakes or hand brakes. Dragging brakes and high wheel temperatures can lead to the following:

- locked axles
- skidded wheels
- scale build up
- thermal cracks
- localised fires at the brakes or bogie
- bush fires
- excessive amounts of smoke
- station or underground fire alarms
- derailment

Section 6.1 to Section 6.5 defines the HWD and CWD alarm and alert models and thresholds for identifying abnormal temperatures for brakes and wheels.

Appendix A describes third generation SST Phoenix site specific thresholds.

6.1. Wheel alarms levels

The following levels of hot wheel alarms shall always be used to refer to the alarm levels:

- high wheel alarms
- medium wheel alarms
- low wheel alarms

6.2. Temperature measurement and calculations

Section 6.2.1 to Section 6.2.4 provides specific requirements for the measurement and calculations of the temperatures used in wheel alarms and alerts.
6.2.1. **Ambient temperature (T\textsubscript{AMB})**

The ambient temperature used in the alarm model calculations shall be obtained from the temperature sensor located on the trackside hut.

Any other methods inclusive or exclusive of the trackside hut ambient temperature sensor used for calculating the ambient temperature can be suggested by the HWD vendor for review by TfNSW.

6.2.2. **Absolute wheel temperatures (T\textsubscript{AW})**

Each wheel shall be divided into two categories, rim and hub.

The HWD system shall provide the means to accurately produce the rim and hub temperatures from the scanned data.

The absolute temperature that shall be used in the alarm model calculations shall be the maximum of the two measured absolute rim and hub temperatures.

The vendor shall demonstrate how these values are calculated for review by TfNSW.

6.2.3. **Relative wheel temperature (T\textsubscript{RW})**

The HWD software shall compute the relative temperature of each wheel against the ambient temperature using relative wheel temperature of a single wheel (T\textsubscript{RW}) = absolute wheel temperature (T\textsubscript{AW}) – ambient temperature (T\textsubscript{AMB})

6.2.4. **Average relative wheel temperature (T\textsubscript{ARW})**

The average relative wheel temperature (T\textsubscript{ARW}) shall be the average of the relative temperatures of all the wheels on the same train-side as the single wheel being checked by the alarm model.

The values used to obtain this average shall be the maximum on each wheel of the two measured rim and hub temperatures.

The average relative temperature shall exclude locomotive wheel temperatures when calculated and shall always be greater than or equal to one. The average relative temperature for locomotives shall be calculated independently (for all locomotives per side of the train).

6.3. **Hot wheel model**

The hot wheel model shall have three user configurable thresholds, two relative temperature thresholds, wheel alarm relative temperature threshold number 1 (S\textsubscript{RW1}) and wheel alarm relative temperature threshold number 2 (S\textsubscript{RW2}) and a comparative wheel alarm ratio threshold (X\textsubscript{W}). If the relative temperature of a wheel is greater than or equal to the relative temperature threshold (S\textsubscript{RW1}), the system shall compare the temperature of the wheel to the average relative temperature of all the wheels on the same train-side as the single wheel being checked by the
alarm model \((T_{ARW})\) of all the wheels on the same train side as that wheel. If the ratio of these two temperatures is greater than or equal to the second determined wheel alarm ratio threshold \((X_W)\), the system shall generate an alarm. If the relative temperature of a wheel is greater than or equal to the relative temperature threshold \((S_{RW2})\) the system shall generate the respective alarm. This model shall produce high, medium and low level alarms.

**Alarm condition:**

The alarm model shall trigger alarms when either of the algorithms below are satisfied.

\[
T_{RW} \geq S_{RW1} \text{ and } T_{RW} / T_{ARW} \geq X_W
\]

\[
T_{RW} \geq S_{RW2}
\]

Where:

\(T_{RW} = \) relative temperature of a single wheel

\(S_{RW1} = \) wheel alarm relative temperature threshold number 1 (user configurable)

\(S_{RW2} = \) wheel alarm relative temperature threshold number 2 (user configurable)

\(T_{ARW} = \) average relative temperature of all the wheels on the same train-side as the single wheel being checked (shall always be greater than one)

\(X_W = \) wheel alarm ratio threshold (user configurable)

**Default thresholds:**

Table 8 shows the recommended default thresholds hot wheel model alarms or alerts.

<table>
<thead>
<tr>
<th>Alarm level</th>
<th>(S_{RW1} (°C))</th>
<th>(X_W)</th>
<th>(S_{RW2} (°C))</th>
</tr>
</thead>
<tbody>
<tr>
<td>High wheel alarm</td>
<td>270</td>
<td>3.5</td>
<td>350</td>
</tr>
<tr>
<td>Medium wheel alarm</td>
<td>210</td>
<td>2.6</td>
<td>270</td>
</tr>
<tr>
<td>Low wheel alarm</td>
<td>160</td>
<td>2.0</td>
<td>0 - disabled</td>
</tr>
</tbody>
</table>

Appendix C contains a graphical representation of the alarm model.

### 6.4. Cold wheel models

The algorithms shown below shall be used for detecting cold wheels and cold brake discs on passenger and freight rolling stock. For a cold wheel alert to be raised for a single wheel either of the following algorithms must prove true and \(C_{AV}\) must be greater than or equal to the min \(C_{AV}\) value defined in the cold wheel alert vehicle parameters table shown below.

If a train is detected as braking through or stopping on a BBT site, or if a train has triggered a hot wheel alarm, all cold wheel alerts shall be disabled for that train.
Alert conditions:

CWD algorithm 1:

\[ C_{AV} \geq \text{Min } C_{AV} \quad \text{and} \quad (C_{AV} - (\alpha \cdot T_{RW})) \geq CWT1 \]

CWD algorithm 2:

\[ C_{AV} \geq \text{Min } C_{AV} \quad \text{and} \quad T_{RW} \leq CWT2 \quad \text{and} \quad C_{AV} \geq CWT3 \]

Where:

- \( C_{AV} \) = average temperature rise of all the relative HWD maximum (rim or hub) temperatures per train side from vehicles of the same vehicle description per consist. Wheel temperatures that have exceeded the low HWD alarm threshold (that is triggered a low, medium or high HWD alarm) must be excluded from this average. Unknown vehicles shall be assessed against the vehicle description with the highest \( C_{AV} \).
- \( T_{RW} \) = relative temperature of a single wheel
- \( CWT1 \) = cold wheel threshold number 1 as per the cold wheel alert vehicle parameter table
- \( CWT2 \) = cold wheel threshold number 2 as per the cold wheel alert vehicle parameter table
- \( CWT3 \) = cold wheel threshold number 3 as per the cold wheel alert vehicle parameter table
- \( \text{Min } C_{AV} \) See table below
- \( \alpha \) = cold wheel algorithm temperature gradient factor

The user shall be able to modify the cold wheel alert vehicle parameters to add, delete and modify any of the values in Table 9.

### Table 9 – Cold wheel alert vehicle parameters

<table>
<thead>
<tr>
<th>Vehicle description</th>
<th>Included AEI tag vehicle code (car class)</th>
<th>Algor 1 active</th>
<th>Algor 2 active</th>
<th>CWT1</th>
<th>CWT2</th>
<th>CWT3</th>
<th>Min ( C_{AV} )</th>
<th>( \alpha )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suburban motor cars</td>
<td>C</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Suburban and Waratah trailer cars</td>
<td>T, DT</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Intercity motor cars</td>
<td>DIM, DCM, DTM, DKM, DJM</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Intercity trailer cars</td>
<td>DIT, DFT, DMT, DDT, DKT, DTD, DCT</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
</tbody>
</table>
### 6.4.1. Cold wheel model parameters

Vehicle description is the description of the vehicles that shall be used for reporting the $C_{AV}$ results for each consist and also used for statistical analysis.

Included AEI tag vehicle codes (vehicle class) are vehicle codes as read from the AEI tags that are included in the corresponding vehicle description and thus shall have the corresponding parameters applied.

Algor 1 active shall be a check box field that allows the corresponding vehicles to be active or inactive for cold wheel alerts algorithm 1. This shall allow cold wheel alerts for certain vehicles to be deactivated if it is deemed that the cold alerts for that specific vehicle are false or unreliable due to obstructions, other heat sources and so on.

Algor 2 active shall be a check box field that allows the corresponding vehicles to be active or inactive for cold wheel alerts algorithm 2. This shall allow cold wheel alerts for certain vehicles

<table>
<thead>
<tr>
<th>Vehicle description</th>
<th>Included AEI tag vehicle code (car class)</th>
<th>Algor 1 active</th>
<th>Algor 2 active</th>
<th>CWT1</th>
<th>CWT2</th>
<th>CWT3</th>
<th>Min $C_{AV}$</th>
<th>$\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangara, Millennium and Waratah motor cars</td>
<td>N</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Tangara, Millennium and Waratah trailer driver cars</td>
<td>D</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Tangara and Oscar motor cars</td>
<td>ON, ONL</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Tangara and Oscar trailer cars</td>
<td>OD</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Endeavour cars</td>
<td>LE, TE</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Xplorer cars</td>
<td>EA, EB, EC</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>XPT power cars</td>
<td>XP</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>XPT trailer cars</td>
<td>XAM, XL, XBR, XF, XFH</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Hunter rail cars</td>
<td>HM, HMT</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Freight</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Passenger</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>30</td>
<td>1.3</td>
</tr>
</tbody>
</table>
to be deactivated if it is deemed that the cold alerts for that specific vehicle are false or unreliable due to obstructions, other heat sources and so on.

CWT1 is the cold wheel threshold number 1 that applies to the corresponding vehicles for cold wheel alert algorithm 1.

CWT2 is the cold wheel threshold number 2 that applies to the corresponding vehicles for cold wheel alert algorithm 2.

CWT3 is the cold wheel threshold number 3 that applies to the corresponding vehicles for cold wheel alert algorithm 2.

Min $C_{AV}$ is the minimum $C_{AV}$ value that must be achieved for cold wheel alerts to be triggered. Vehicle data for cold wheel alert statistics shall also only be included if the minimum $C_{AV}$ value has been exceeded.

$\alpha$ is the cold wheel algorithm temperature gradient factor that applies to the corresponding vehicles for cold wheel alert algorithm 1.

Note: The vehicle description rows for passenger and freight are generic parameter rows for vehicles whose AEI tags have not been included in the cold wheel alert vehicle parameter table or whose AEI tags have not been detected. Identification for passenger or freight shall be based on axle spacing if no AEI tags have been detected.

6.5. Brake cut-out models

TS TOC.1 specifies several requirements for passenger and freight trains operating in the metropolitan rail area for brake performance and brake cut-outs (BC) on cold wheels. Whilst enforcement has previously been difficult to enforce now with the assistance of brake or wheel temperature data from the track control mark (TCM) systems and cold wheel alert algorithms this can be monitored and actioned.

Section 6.5.1 to Section 6.5.5 present the BC alert models and thresholds for identifying brake temperature scenarios that do not comply with the TS TOC.1 requirements.

6.5.1. Types of alerts

BC alerts shall only have one alert level that is triggered by the following four types of BC alerts:

1. BC alert 1 – refers to freight trains with BC >10%
2. BC alert 2 – refers to freight trains with BC in the last 3 wagons
3. BC alert 3 – refers to passenger trains with BC >12.5%
4. BC alert 4 – refers to passenger trains with BC in the terminal end
The BC alert types terminology above shall be used to refer to the respective defective brake conditions in TS TOC.1.

### 6.5.2. Model BC1 - freight greater than 10%

This model shall determine the percentage of freight wagons, excluding locomotives, with cold wheels in a whole freight train by comparing the number of wagons with all wheels triggering CWD alerts \((N_{cw})\) against the total number of wagons in the train \((N_w)\). The alert is triggered when the percentage is greater than 10%. The model shall produce only BC alerts.

**Alert condition:**

The alert model shall trigger alerts when the condition below is satisfied.

\[
\frac{N_{cw}}{N_w} > 0.10
\]

Where:

- \(N_{cw}\) = number of wagons with all wheels triggering CWD alerts.
- \(N_w\) = total number of wagons in the train (that is, total freight vehicles excluding locomotives)

### 6.5.3. Model BC2 - freight last three wagons

This model shall determine if the brakes are cut-out on any of the last three wagons in a freight train. The alert is triggered if any of the last 3 wagons have triggered CWD alerts on all wheels. The model shall produce only BC alerts.

### 6.5.4. Model BC3 - passenger greater than 12.5%

This model shall determine the percentage of passenger carriages, excluding locomotives, with cold wheels in a whole train by comparing the number of carriages with all wheels triggering CWD alerts \((N_{cc})\) against the total number of carriages in the train \((N_c)\). The alert is triggered when the percentage is greater than 12.5%. The model shall produce only BC alerts.

**Alert condition:**

The alert model shall trigger alerts when the condition below is satisfied.

\[
\frac{N_{cc}}{N_c} > 0.125
\]

Where:

- \(N_{cc}\) = number of carriages with all wheels triggering cold wheel alerts
- \(N_c\) = total number of carriages in the train
6.5.5. **Model BC4 - passenger terminal end**

This model shall determine if the brakes are cut-out on either of the terminal end carriages on a passenger train. The alert is triggered if either of the terminal end carriages has triggered CWD alerts on all wheels. The model shall produce only BC alerts.

7. **Alarm and alert model exceptions**

There are instances where false alarms or alerts can be triggered due to the influence of an external source of heat or train operating scenario that does not directly represent a bearing or wheel temperature fault that requires an alarm or alert to be generated.

Section 7.1 and Section 7.2 present the alarm and alert exception models and thresholds for preventing false alarms and alerts due to the respective conditions.

7.1. **E1 - bearing alarms due to wheel temperature or wheel alarms**

*Note: This type of alarm and alert exception only applies to HBD scanners that view the underside of axle bearings from directly below the bearing.*

Dynamic train testing has shown that hot wheels and hot wheel mounted brake discs can influence the temperatures recorded by HBD scanners that view the underside of bearings adjacent to hot wheels or brake discs. In order to prevent false and misleading bearing alarms (low bearing alerts, warm and hot bearing alarms) being triggered due to hot wheels the model and parameters shown in Table 10 will exclude some of the bearing models from triggering and will elevate the absolute bearing temperature model thresholds based on the wheel temperature that has been detected. These exceptions will only be applied to bearing positions where a maximum wheel temperature has exceeded the defined threshold at the same location. The exception model shown below is based on the recommendation from Sydney Trains.

Exception conditions:

1. at all wheel positions where the maximum absolute wheel temperature threshold ($E_{1, AW}$) has been exceeded bearing alarm or alert models P2, F2, P3 and F3 shall be disabled

2. for remaining bearing alarm models P1 and F1 the absolute temperature thresholds shall be changed to the values shown in Table 10

3. according to the maximum absolute wheel temperature of the wheel at the same location.

4. the disabling of alarm models and the modification of alarm model parameters shall only be applied at the wheel and bearing positions where the maximum wheel temperature threshold has been exceeded and shall only remain in place for the respective train pass.
Table 10 - P1 and F2 $S_{SB}$ according to $E_{1AW}$

<table>
<thead>
<tr>
<th>Level</th>
<th>$E_{1AW}$ (°C)</th>
<th>Model P1 warm $S_{SB}$ (°C)</th>
<th>Model P1 hot $S_{SB}$ (°C)</th>
<th>Model F1 $S_{SBW}$ (°C)</th>
<th>Model F1 $S_{SBH}$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>290</td>
<td>105</td>
<td>115</td>
<td>105</td>
<td>115</td>
</tr>
<tr>
<td>2</td>
<td>260</td>
<td>100</td>
<td>110</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>1</td>
<td>230</td>
<td>95</td>
<td>105</td>
<td>95</td>
<td>105</td>
</tr>
</tbody>
</table>

Each of these 3 exception thresholds shall be administrator configurable.

7.2. E2 - train braking through the site

Trains may apply brakes as they pass over the HWD scanners due to train operating conditions at the BBT site. When brakes are applied, localised hot spots can occur on the wheel rim back or on the brake discs that can trigger HWD wheel alarms and alerts. Stopping a train for inspection under this scenario provides no benefit to TfNSW and will only result in network delays and confusion. The model and parameters shown below will prevent wheel alarms and alerts being triggered when the train is detected as decelerating at a rate greater than the specified threshold.

Exception conditions:

1. the deceleration rate shall be calculated between every axle based on the individual axle speeds
2. for all consists where the maximum deceleration rate (DR) has exceeded the value shown in Table 11 $S_{RW1}$ and $S_{RW2}$ shall be increased for all wheel temperatures recorded on the consist
3. all $X_{W}$ threshold values shall remain as specified in Section 6.3

Table 11 – $S_{RW1}$ and $S_{RW2}$ according to DR

<table>
<thead>
<tr>
<th></th>
<th>$S_{RW1}$ (°C) DR &gt; 0.3 m/s²</th>
<th>$S_{RW1}$ (°C) DR &gt; 0.6 m/s²</th>
<th>$S_{RW2}$ (°C) DR &gt; 0.3 m/s²</th>
<th>$S_{RW2}$ (°C) DR &gt; 0.6 m/s²</th>
</tr>
</thead>
<tbody>
<tr>
<td>High wheel alarm</td>
<td>300</td>
<td>330</td>
<td>380</td>
<td>410</td>
</tr>
<tr>
<td>Medium wheel alarm</td>
<td>240</td>
<td>270</td>
<td>300</td>
<td>330</td>
</tr>
<tr>
<td>Low wheel alarm</td>
<td>190</td>
<td>220</td>
<td>0 - disabled</td>
<td>0 - disabled</td>
</tr>
</tbody>
</table>

Each of these 3 DR thresholds and the exception thresholds shall be administrator configurable.
## Appendix A  Third generation SST Phoenix site specific thresholds

Table 12 to Table 22 show the thresholds for third generation SST Phoenix sites.

### Table 12 – Bearing model P1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{AB}$ (hot alarm)</td>
<td>100</td>
<td>100</td>
<td>105</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>$S_{AB}$ (warm alarm)</td>
<td>90</td>
<td>90</td>
<td>95</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

### Table 13 – Bearing model P2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{VDB}$ (warm alarm)</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>$S_{VDB}$ (low alert)</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

### Table 14 – Bearing model P3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{ADB}$ (low alert)</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

### Table 15 – Bearing model F1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{ABH}$ (hot alarm)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>$S_{ABW}$ (warm alarm)</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>$S_{LOW}$</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>$S_{HIGH}$</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

### Table 16 – Bearing model F2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{VDB}$ (warm alarm)</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>$S_{VDB}$ (low alert)</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>
Table 17 – Bearing model F3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{ADB}$ (low alert)</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 18 – Hot wheel models

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{RW1}$ (high alarm)</td>
<td>270</td>
<td>270</td>
<td>270</td>
<td>270</td>
<td>270</td>
</tr>
<tr>
<td>$S_{RW1}$ (medium alarm)</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
</tr>
<tr>
<td>$S_{RW1}$ (low alarm)</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>$S_{RW2}$ (high alarm)</td>
<td>350</td>
<td>350</td>
<td>410</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>$S_{RW2}$ (medium alarm)</td>
<td>270</td>
<td>270</td>
<td>330</td>
<td>270</td>
<td>270</td>
</tr>
<tr>
<td>$S_{RW2}$ (low alarm)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$X_{W}$ (high alarm)</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>$X_{W}$ (medium alarm)</td>
<td>2.6</td>
<td>2.6</td>
<td>2.6</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>$X_{W}$ (low alarm)</td>
<td>2</td>
<td>2</td>
<td>2.2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 19 – Exception model E1 (for P1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 3 – $E_{1AW}$</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td>Level 3 – $H_{SA}$</td>
<td>115</td>
<td>115</td>
<td>130</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Level 3 – $W_{SA}$</td>
<td>105</td>
<td>105</td>
<td>120</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>Level 2 – $E_{1AW}$</td>
<td>260</td>
<td>260</td>
<td>260</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>Level 2 – $H_{SA}$</td>
<td>110</td>
<td>110</td>
<td>125</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>Level 2 – $W_{SA}$</td>
<td>100</td>
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<tr>
<td>Level 1 – $E_{1AW}$</td>
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</tr>
<tr>
<td>Level 1 – $H_{SA}$</td>
<td>105</td>
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<td>120</td>
<td>105</td>
<td>105</td>
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<tr>
<td>Level 1 – $W_{SA}$</td>
<td>95</td>
<td>95</td>
<td>110</td>
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</table>

Table 20 – Exception model E1 (for F1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 3 – $E_{1AW}$</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
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<tr>
<td>Level 3 – $S_{AH}$</td>
<td>115</td>
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<td>130</td>
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<tr>
<td>Level 3 – $S_{BW}$</td>
<td>105</td>
<td>105</td>
<td>120</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>Parameter</td>
<td>Corrimal Up</td>
<td>Corrimal Dn</td>
<td>Springwood Up</td>
<td>Springwood Dn</td>
<td>Lithgow Up</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------------</td>
<td>---------------</td>
<td>------------</td>
</tr>
<tr>
<td>Level 2 – $E_{1AW}$</td>
<td>260</td>
<td>260</td>
<td>260</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>Level 2 – $S_{ABH}$</td>
<td>110</td>
<td>110</td>
<td>125</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>Level 2 – $S_{ABW}$</td>
<td>100</td>
<td>100</td>
<td>115</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Level 1 – $E_{1AW}$</td>
<td>230</td>
<td>230</td>
<td>230</td>
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<td>Level 1 – $S_{ABH}$</td>
<td>105</td>
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<td>120</td>
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<tr>
<td>Level 1 – $S_{ABW}$</td>
<td>95</td>
<td>95</td>
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**Table 21 – Exception model E2**

<table>
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<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SR_{1}$ (high alarm) - DR1</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>$SR_{1}$ (medium alarm) - DR1</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>$SR_{1}$ (low alarm) - DR1</td>
<td>190</td>
<td>190</td>
<td>190</td>
<td>190</td>
<td>190</td>
</tr>
<tr>
<td>$SR_{2}$ (high alarm) - DR1</td>
<td>380</td>
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<td>430</td>
<td>380</td>
<td>380</td>
</tr>
<tr>
<td>$SR_{2}$ (medium alarm) - DR1</td>
<td>300</td>
<td>300</td>
<td>350</td>
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<td>300</td>
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<tr>
<td>$SR_{2}$ (low alarm) - DR1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$SR_{1}$ (high alarm) - DR2</td>
<td>330</td>
<td>330</td>
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<td>330</td>
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</tr>
<tr>
<td>$SR_{1}$ (medium alarm) - DR2</td>
<td>270</td>
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<td>$SR_{1}$ (low alarm) - DR2</td>
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<td>$SR_{2}$ (high alarm) - DR2</td>
<td>410</td>
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<td>430</td>
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<td>410</td>
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<tr>
<td>$SR_{2}$ (medium alarm) - DR2</td>
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<td>330</td>
<td>350</td>
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<tr>
<td>$SR_{2}$ (low alarm) - DR2</td>
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<td>0</td>
<td>0</td>
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<td>DR1</td>
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</table>

**Table 22 – Cold wheel alert models**

<table>
<thead>
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<th>Parameter</th>
<th>Corrimal Up</th>
<th>Corrimal Dn</th>
<th>Springwood Up</th>
<th>Springwood Dn</th>
<th>Lithgow Up</th>
</tr>
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<tbody>
<tr>
<td>Algor. 1 active</td>
<td>yes</td>
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<td>Algor. 2 active</td>
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<td>CWT1</td>
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<tr>
<td>CWT2</td>
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<tr>
<td>CWT3</td>
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<td>Alpha</td>
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<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
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</tbody>
</table>
Appendix B  Graphical representation of HBD alarms and alerts model (default thresholds)

Figure 1 is a graphical representation of HBD alarm or model P1 or P2 and F2 alerts (default thresholds).

![HBD Alarm/Alert Settings](image)

**Figure 1 – HBD alarm or model P1 or P2 and F2 alerts**

Figure 2 is a graphical representation of HBD alarm or model F1 alerts.

![HBD alarm or alert settings](image)

**Figure 2 – HBD alarm or model F1 alerts**
Appendix C  Graphical representation of HWD alarm model (default thresholds)

Figure 3 is a graphical representation of HWD alarm settings.

Figure 3 – HWD alarm settings