Transport Asset Standards Authority

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Standard

Bearing and Brake Temperature Alarm and Alert Models

Version 4.0

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Important message

For queries regarding this document, please email the ASA at
standards@transport.nsw.gov.au or visit www.transport.nsw.gov.au

Standard governance

Owner: Director Fleet Engineering, Asset Management Branch

Authoriser: Director Engineering, Asset Management Branch

Approver: Executive Director, Asset Management Branch on behalf of the AMB Configuration Control Board

Document history

Version	Summary of changes
1.0	First issue 17 January 2017
2.0	Second issue 6 April 2018. Changes to previous content in this version are summarised as follows; general updates; addition of new parameters; algorithm changes; reduced thresholds; removal of identified duplicate compensations; and changes resulting from the analysis of third generation BBT wheel and bearing temperature data.
3.0	Third issue 16 December 2019. Changes to previous content in this version are summarised as follows; P1 algorithm changes; hot wheel alarm passenger fleet grouping; BC alert priorities; Appendix A updated to BBT site-specific threshold tables; and site-specific thresholds for Engadine Up to compensate for trains braking through the site
4.0	Changes to previous content in this version are summarised as follows: added cold wheel alert vehicle parameters to Intercity cars (to include NIF) and corrected vehicle description for Oscar Cars; added new section for other exceptions and functionalities; updated Engadine Up site-specific thresholds; added tables for Rhodes Down site-specific thresholds and Rhodes Up site-specific thresholds. Added extreme hot bearing alarm model and medium bearing differential alert for P3 and F3 models.

Preface

The Asset Management Branch (AMB), formerly known as 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 and brake temperature wayside systems operating in the TfNSW Metropolitan Heavy Rail Network.

This standard has been developed in conjunction with Sydney Trains.

This is a fourth issue. Changes to previous content in this version are summarised as follows:

- Added cold wheel alert vehicle parameters DN, DND, DNL, DD, DDA, DT AEI tag vehicle codes to Intercity cars and corrected vehicle description for Oscar Cars ON, ONL, OD by removing reference to Tangara.
- Added new section for other exceptions and functionalities.
- Updated Engadine Up site-specific thresholds to add site-specific threshold to SRW1 '0 (only RailCorp passenger vehicles)'.

- Added tables for Rhodes Down site-specific thresholds and Rhodes Up site-specific thresholds.
- Added extreme hot bearing alarm model and medium bearing differential alert for P3 and F3 models.

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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, the train's speed and the train's direction while passing a site.

HBD subsystems measure all bearing temperatures as a consist passes a site. The HWD subsystem 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.

BBT 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 automatically communicated to freight train drivers using a Without Brakevan – 450.050 MHz WB radio.

As of 2020, two generations of BBT systems from different vendors are installed in the TfNSW Metropolitan Heavy Rail Network. The second generation BBT systems are Australian VEIC Technology (AVT) Rail Systems (installed in 2005) and the third generation BBT systems are vaSIG (voestalpine SIGNALING) installed in 2012 and 2019.

As each of the different generation systems were supplied by different vendors and their proposed alarm models and thresholds are different, it 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. A standard is therefore required to ensure all systems apply the same thresholds, alarm and alert models.

2. Purpose

This standard defines the HBD, HWD and CWD alarm and alert models and thresholds for all BBT systems in the TfNSW Metropolitan Heavy Rail Network. The information is crucial to BBT system vendors, rolling stock operators and BBT trackside system users and maintainers. Having a standard set of alarm and alert models and thresholds defined results in a consistent approach to HBD, HWD and CWD alarm and alert definitions, which are independent of the system producing them.

This standard allows BBT system vendors to provide equipment with the required alarm and alert models and thresholds to ensure that the operation of all BBT trackside systems is consistent within the TfNSW Metropolitan Heavy Rail Network.

This standard informs rolling stock operators about BBT trackside systems used to monitor all rolling stock in the TfNSW Metropolitan Heavy Rail Network 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 installed in the TfNSW Metropolitan Heavy Rail Network (Refer to TS TOC 1 *Train Operating Conditions (TOC) Manual – General Instructions*, which defines the areas associated with the network.) and the Country Regional Network.

2.2. Application

This standard applies to all BBT trackside systems.

3. Reference documents

The following document is cited in the text.

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 or train controller. Alarm notifications primarily occur as a pop up and audible tone

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

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

CRN Country Rail Network

CWD cold wheel detector

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

vaSIG voestalpine SIGNALING (third generation BBT vendor)

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

Table 1- Algorithm symbols

Symbol	Definition
α	Cold wheel algorithm temperature gradient factor
C_{AV}	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.
CWT1	Cold wheel threshold number 1 that applies to the corresponding vehicles for cold wheel alert algorithm 1
CWT2	Cold wheel threshold number 2 that applies to the corresponding vehicles for cold wheel alert algorithm 2
CWT3	Cold wheel threshold number 3 that applies to the corresponding vehicles for cold wheel alert algorithm 2
$E1_{AW}$	E1 absolute wheel temperature threshold
N_C	Total number of passenger carriages in the train
N_{CC}	Number of passenger carriages with all wheels triggering cold wheel alerts
N_{CW}	Number of wagons with all wheels triggering cold wheel alerts
N_W	Total number of wagons in the train (that is, total freight vehicles excluding locomotives)
S_{AB}	Absolute bearing temperature threshold
S_{ABE}	Absolute bearing temperature threshold – Extreme
S_{ABH}	Absolute bearing temperature threshold – Hot
S_{ABW}	Absolute bearing temperature threshold - Warm
S_{ADB1}	Axle differential bearing temperature threshold number 1
S_{ADB2}	Axle differential bearing temperature threshold number 2
S_{HIGH}	High ambient temperature setting, marking the end of the ambient temperature compensation zone
S_{LOW}	Low ambient temperature setting, marking the start of the ambient temperature compensation zone
S_{RW1}	Relative wheel temperature threshold number 1
S_{RW2}	Relative wheel temperature threshold number 2

Symbol	Definition
S_{VDB}	Vehicle differential bearing temperature threshold
T_{AABV}	Average absolute bearing temperature of all the bearings on the same vehicle as the single bearing being checked
T_{AB}	Maximum absolute bearing temperature of each bearing measured by the HBD subsystem
T_{ABA}	Absolute bearing temperature of the adjacent bearing on the same axle as the single bearing being checked
T_{AABL}	Average absolute bearing temperature of all the bearings on the left train-side of the train (including locomotives)
T_{AABR}	Average absolute bearing temperature of all the bearings on the right train-side of the train (including locomotives)
T_{AMB}	Ambient temperature
T_{ARW}	Average relative temperature of all the wheels on the same train-side as the single wheel being checked by the alarm model
T_{ARWB}	Average relative temperature of all the wheels on the bogies which have all wheels cold
T_{ARWV}	Average relative temperature of all the wheels on the vehicles which have all wheels cold
T_{AW}	Absolute temperature of a single wheel
T_{RW}	Relative temperature of a single wheel
X_W	Wheel alarm ratio threshold

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 vaSIG Phoenix MB site-specific thresholds.

5.1. Bearing alarm and alert levels

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

- extreme bearing alarms
- hot bearing alarms
- warm bearing alarms
- medium bearing alerts
- low bearing alerts

5.2. Model groups

The hot bearing detector (HBD) subsystem 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. The detected bearing temperatures from freight and all other trains (including unidentified) 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.

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 per bearing.

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 only the 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 5.3.6 provides specific requirements for the measurement and calculations of the temperatures used in bearing alarms and alerts.

5.3.1. Absolute bearing temperature (T_{AB})

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

5.3.2. Average absolute bearing temperature (T_{AABV})

The average absolute bearing temperature (T_{AABV}) 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_{ABA})

The absolute bearing temperature adjacent (T_{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. Average absolute bearing temperature left (T_{AABL})

The average absolute bearing temperature left (T_{AABL}) is the average absolute bearing temperature of all the bearings on the left train-side of the train (including locomotives).The vendor shall explain and document how T_{AABL} is calculated for TfNSW's review.

5.3.5. Average absolute bearing temperature right (T_{AABR})

The average absolute bearing temperature right (T_{AABR}) is the average absolute bearing temperature of all the bearings on the right train-side of the train (including locomotives). The vendor shall explain and document how the T_{AABR} is calculated for TfNSW's review.

5.3.6. Ambient temperature (T_{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 bearing and brake temperature (BBT) vendor for review by TfNSW.

5.4. Thresholds

The alarm or alert thresholds should be dependent on the vehicle class detected using the automatic equipment identification (AEI) tag readers. If the system can achieve this, then the thresholds for each of the vehicle classes shall be administrator configurable. In addition, there may be no need for separate freight and passenger alarm or alert models as the vehicle class may be 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

Section 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 use configurable absolute temperature threshold settings for the extreme absolute bearing temperature threshold (S_{ABE}), hot absolute bearing temperature threshold (S_{ABH}) and the warm absolute bearing temperature threshold (S_{ABW}) respectively.

Model P1 shall use ambient temperature compensation for warm bearing 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_{LOW}) and the high ambient temperature setting marking the end of the ambient temperature compensation zone (S_{HIGH}). The model shall compare each measured absolute bearing temperature (T_{AB}) against the following conditions to produce hot and warm bearing alarms only.

Alarm conditions:

The alarm model shall trigger an extreme bearing alarm when the following condition (condition P1.1) is satisfied.

$T_{AB} \geq S_{ABE}$

The alarm model shall trigger a hot bearing alarm when the following condition (condition P1.2) is satisfied.

$T_{AB} \geq S_{ABH}$

The alarm model shall trigger a warm bearing alarm when the following condition (condition P1.3 or condition P1.4) is satisfied.

$T_{AB} \geq S_{ABW}$ AND $T_{AMB} \leq S_{LOW}$

or

$T_{AB} \geq S_{ABW}$ AND $T_{AB} \geq m * T_{AMB} + c$

Where:

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

$$c = S_{ABW} - \frac{S_{ABH} - S_{ABW}}{S_{HIGH} - S_{LOW}} * S_{LOW}$$

T_{AB} = maximum absolute bearing temperature of each bearing measured by the HBD subsystem

T_{AMB} = ambient temperature

S_{ABE} = absolute bearing temperature threshold - extreme (administrator configurable)

S_{ABH} = absolute bearing temperature threshold - hot (administrator configurable)

S_{ABW} = absolute bearing temperature threshold - warm (administrator configurable)

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

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

Default thresholds:

Table 2 shows the default thresholds for model P1 alarms.

Table 2 – Model P1 thresholds

Parameter	(°C)	Description
S_{ABE}	130	Extreme bearing alarm absolute temperature threshold (default)
S_{ABH}	100	Hot bearing alarm absolute temperature threshold (default)
S_{ABW}	90	Warm bearing alarm absolute temperature threshold (default)
S_{LOW}	150	Low ambient temperature setting (default high to suppress)
S_{HIGH}	151	High ambient temperature setting (default high to suppress)

Note: E1 alarm and alert model exceptions are applicable to the P1 model.

Figure 2 in Appendix B contains a graphical representation of the P1 alarm models.

5.5.2. Model P2

Model P2 shall have a configurable vehicle differential bearing 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_{AABV}). The alarm or alert is triggered when the maximum absolute temperature of a bearing is greater than or equal to the total of T_{AABV} 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 following condition (condition P2.1) is satisfied.

$$T_{AB} \geq (T_{AABV} + S_{VDB})$$

Where:

T_{AB} = maximum absolute bearing temperature of each bearing measured by the HBD subsystem

S_{VDB} = vehicle differential bearing temperature threshold (user configurable)

T_{AABV} = average absolute bearing 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

Alarm or alert level	S_{VDB} (°C)
Warm bearing alarm	50
Low bearing alert	30

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 axle differential bearing temperature threshold (S_{ADB1}). The model shall compare each absolute bearing temperature (T_{AB}) against the sum of the user defined threshold (S_{ADB1}), the absolute temperature of the adjacent bearing on the same axle as the single bearing being checked (T_{ABA}), and the absolute average absolute bearing temperature difference between train sides (abs (T_{AABL} – T_{AABR})). The alert is triggered when the absolute temperature of a bearing is greater than or equal to the two parts of the model conditions. The model shall produce only low bearing alerts.

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

Alert conditions:

The alert model shall trigger alerts when the following conditions (condition P3.1 and condition P3.2) are all satisfied.

$$T_{AB} \geq (T_{ABA} + S_{ADB1} + (\text{abs}\ (T_{AABL} - T_{AABR})))$$

and

$$T_{AB} \geq (T_{AMB} + S_{ADB2})$$

Where:

T_{AB} = maximum absolute bearing temperature of each bearing measured by the HBD subsystem

T_{ABA} = absolute bearing temperature of the adjacent bearing on the same axle as the single bearing being checked

T_{AABL} = average absolute bearing temperature of all the bearings on the left train-side of the train (including locomotives)

T_{AABR} = average absolute bearing temperature of all the bearings on the right train-side of the train (including locomotives)

T_{AMB} = ambient temperature

S_{ADB1} = axle differential bearing temperature threshold number 1– across a single axle administrator configurable

S_{ADB2} = axle differential bearing temperature threshold number 2 – relative to ambient temperature (administrator configurable)

Default thresholds:

Table 4 shows the recommended default thresholds for model P3 alerts.

Table 4 – Model P3 thresholds

Alert level	S_{ADB1} (°C)	S_{ADB2} (°C)
Medium bearing differential alert	27	30
Low bearing differential alert	15	30

5.6. Freight and other bearing alarm or alert models

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

5.6.1. Model F1

Model F1 shall use configurable absolute temperature threshold settings for the extreme absolute bearing temperature threshold (S_{ABE}), hot absolute bearing temperature threshold (S_{ABH}) and the warm absolute bearing temperature threshold (S_{ABW}) respectively.

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_{LOW}) and the high ambient temperature setting marking the end of the ambient temperature compensation zone (S_{HIGH}). The model shall compare each measured absolute bearing temperature (T_{AB}) against the following conditions to produce hot and warm bearing alarms only.

Alarm conditions:

The alarm model shall trigger an extreme bearing alarm when the following condition (condition F1.1) is satisfied.

$T_{AB} \geq S_{ABE}$

The alarm model shall trigger a hot bearing alarm when the following condition (condition F1,2) is satisfied.

$T_{AB} \geq S_{ABH}$

The alarm model shall trigger a warm bearing alarm when the following conditions (condition F1.3 or condition F1.4) are satisfied.

$T_{AB} \geq S_{ABW}$ AND $T_{AMB} \leq S_{LOW}$

or

$T_{AB} \geq S_{ABW}$ AND $T_{AB} \geq m * T_{AMB} + c$

Where:

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

$$c = S_{ABW} - \frac{S_{ABH} - S_{ABW}}{S_{HIGH} - S_{LOW}} * S_{LOW}$$

T_{AB} = maximum absolute bearing temperature of each bearing measured by the HBD subsystem

T_{AMB} = ambient temperature

S_{ABE} = absolute bearing temperature threshold – extreme (administrator configurable)

S_{ABH} = absolute bearing temperature threshold – hot (administrator configurable)

S_{ABW} = absolute bearing temperature threshold – warm (administrator configurable)

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

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

Default thresholds:

Table 5 shows the default settings for model F1 alarms.

Table 5 – Model F1 thresholds

Parameter	(°C)	Description
S_{ABE}	130	Extreme bearing alarm absolute temperature threshold (default)
S_{ABH}	100	Hot bearing alarm absolute temperature threshold (default)
S_{ABW}	90	Warm bearing alarm absolute temperature threshold (default)
S_{LOW}	20	Low ambient temperature setting
S_{HIGH}	30	High ambient temperature setting

Note: E1 alarm and alert model exceptions are applicable to the F1 model.

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

5.6.2. Model F2

Model F2 shall have a configurable vehicle differential bearing temperature threshold (S_{VDB}). The model shall compare each absolute bearing temperature (TAB) against the sum of the user defined threshold (S_{VDB}) and the average absolute bearing temperature (T_{AABV}). The alarm is triggered when the absolute temperature of a bearing is greater than or equal to the total of (T_{AABV} + 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 following condition (condition F2.1) is satisfied.

$T_{AB} \geq (T_{AABV} + S_{VDB})$

Where:

T_{AB} = maximum absolute bearing temperature of each bearing measured by the HBD subsystem

S_{VDB} = vehicle differential bearing temperature threshold (user configurable)

T_{AABV} = average absolute bearing 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 6 – Model F2 thresholds

Alarm or alert level	S_{VDB} (°C)
Warm bearing alarm	50
Low bearing alert	30

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 bearing temperature threshold (S_{ADB}). The model shall compare each absolute bearing temperature (T_{AB}) against the sum of the user defined threshold (S_{ADB1}), the absolute bearing temperature adjacent (T_{ABA}) and the absolute average absolute bearing temperature difference between train sides (abs (T_{AABL} – T_{AABR})). The alert is triggered when the absolute temperature of a bearing is greater than or equal to the two parts of the model condition. The model shall produce only low bearing alerts.

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

Alert conditions:

The alert model shall trigger alerts when the following conditions (condition F3.1 and condition F3.2) are all satisfied.

$T_{AB} \geq (T_{ABA} + S_{ADB1} + (\text{abs}\ (T_{AABL} - T_{AABR})))$

and

$T_{AB} \geq (T_{AMB} + S_{ADB2})$

Where:

T_{AB} = maximum absolute bearing temperature of each bearing measured by the HBD subsystem

T_{ABA} = absolute bearing temperature of the adjacent bearing on the same axle as the single bearing being checked

T_{AABL} = average absolute bearing temperature of all the bearings on the left train-side of the train (including locomotives)

T_{AABR} = average absolute bearing temperature of all the bearings on the right train-side of the train (including locomotives)

T_{AMB} = ambient temperature

S_{ADB1} = axle differential bearing temperature threshold number 1 (user configurable) – across a single axle (user configurable)

S_{ADB2} = axle differential bearing temperature threshold number 2 (user configurable) – relative to ambient temperature (user configurable)

T_{ABA} = absolute bearing 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 alerts.

Table 7 – Model F3 thresholds

Alert level	S_{ADB1} (°C)	S_{ADB2} (°C)
Medium bearing differential alert	37	40
Low bearing differential alert	25	40

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 hot wheel detector (HWD) and cold wheel detector (CWD) alarm and alert models and thresholds for identifying abnormal temperatures for brakes and wheels.

Appendix A describes the site-specific thresholds which are exceptions to the recommended default thresholds.

6.1. Wheel alarm 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 6.2.6 provides specific requirements for the measurement and calculations of the temperatures used in wheel alarms and alerts.

6.2.1. Ambient temperature (T_{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 BBT vendor for review by TfNSW.

6.2.2. Absolute wheel temperatures (T_{AW})

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

The HWD subsystem 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_{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_{RW}) = absolute wheel temperature (T_{AW}) – ambient temperature (T_{AMB}).

6.2.4. Average relative wheel temperature (T_{ARW})

The average relative wheel temperature (T_{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.

For freight trains - the average relative temperature for locomotives shall be calculated independently to the wagons, that is, for all locomotives per side of the train.

For passenger trains - the average relative wheel temperature shall be calculated by grouping like vehicles as per the cold wheel alert vehicle groups in Table 9. That is, T_{ARW} will be calculated for all like vehicles (for example, motor cars) per side of the train.

6.2.5. Average relative wheel temperature – cold vehicles (T_{ARWV})

The average relative wheel temperature for vehicles (T_{ARWV}) shall be the average of the relative temperatures of all the wheels on the vehicles which have all wheels detected as 'cold'. The values used to obtain this average shall be the maximum on each wheel of the two measured rim and hub temperatures.

6.2.6. Average relative wheel temperature – cold bogies (T_{ARWB})

The average relative wheel temperature for bogies (T_{ARWB}) shall be the average of the relative temperatures of all the wheels on the bogies which have all wheels detected as cold. The values used to obtain this average shall be the maximum on each wheel of the two measured rim and hub temperatures.

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_{RW1}) and wheel alarm relative temperature threshold number 2 (S_{RW2}) and a comparative wheel alarm ratio threshold (X_W). If the maximum relative temperature of a wheel is greater than or equal to the relative temperature threshold (S_{RW1}), the system shall compare the temperature of the wheel to the average relative wheel temperature (T_{ARW}) 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 wheel alarms.

Alarm condition:

The alarm model shall trigger alarms when either of the following conditions are satisfied.

$T_{RW} \geq S_{RW1}$ and $T_{RW} / T_{ARW} \geq X_W$

or

$T_{RW} \geq S_{RW2}$

Where:

T_{RW} = relative temperature of a single wheel

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

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

T_{ARW} = average relative temperature of 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 8 – Hot wheel model thresholds

Alarm level	S_{RW1} (°C)	X_W	S_{RW2} (°C)
High wheel alarm	270	3.5	350
Medium wheel alarm	210	2.6	270
Low wheel alarm	160	2.0	0 - disabled

Note: E2 alarm and alert model exceptions are applicable to the hot wheel model.

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 conditions shall prove true and C_{AV} shall be greater than or equal to the minimum C_{AV} (Min C_{AV}) value defined in Table 9.

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:

$C_{AV} \geq \text{Min } C_{AV}$ and $(C_{AV} - (\alpha * T_{RW})) \geq CWT1$

CWD algorithm 2:

$C_{AV} \geq \text{Min } C_{AV}$ and $T_{RW} \leq CWT2$ and $C_{AV} \geq CWT3$

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. 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

Min C_{AV} = see Table 9

α = 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

Vehicle description	Included AEI tag vehicle codes (vehicle class)	Algor 1 active	Algor 2 active	CWT1	CWT2	CWT3	Min C_{AV}	α
Suburban motor cars	C	Yes	Yes	25	10	25	30	1.3
Suburban and Waratah trailer cars	T, DT	Yes	Yes	25	10	25	30	1.3
Intercity motor cars (Camshaft)	DIM, DCM, DTM	Yes	Yes	25	10	25	30	1.3
Intercity motor cars (Chopper)	DJM, DKM, DN, DND, DNL	Yes	Yes	25	10	25	30	1.3
Intercity trailer cars	DIT, DFT, DMT, DDT, DKT, DTD, DCT, DD, DDA, DT	Yes	Yes	25	10	25	30	1.3
Tangara, Millennium and Waratah motor cars	N	Yes	Yes	25	10	25	30	1.3
Tangara, Millennium and Waratah trailer driver cars	D	Yes	Yes	25	10	25	30	1.3
Oscar motor cars	ON, ONL	Yes	Yes	25	10	25	30	1.3
Oscar trailer cars	OD	Yes	Yes	25	10	25	30	1.3
Endeavour cars	LE, TE	Yes	Yes	25	10	25	30	1.3
Xplorer cars	EA, EB, EC	Yes	Yes	25	10	25	30	1.3

Vehicle description	Included AEI tag vehicle codes (vehicle class)	Algor 1 active	Algor 2 active	CWT1	CWT2	CWT3	Min C_{AV}	α
XPT power cars	XP	Yes	Yes	25	10	25	30	1.3
XPT trailer cars	XAM, XL, XBR, XF, XFH	Yes	Yes	25	10	25	30	1.3
Hunter rail cars	HM, HMT	Yes	Yes	25	10	25	30	1.3
Freight		Yes	Yes	25	10	25	30	1.3
Passenger		Yes	Yes	25	10	25	30	1.3
Locomotives		Yes	Yes	25	10	25	30	1.3

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 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 shall 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.

α 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, freight and locomotives are generic parameter rows for vehicles whose AEI tags have not been included in Table 9. Identification for passenger, freight and locomotives 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 brake performance and brake cut-outs (BC) for passenger and freight trains operating in the TfNSW Metropolitan Heavy Rail Network. Whilst enforcement has previously been difficult to manage, now with the assistance of wheel temperature data and cold wheel alerts from the BBT systems this can be monitored and actioned.

Section 6.5.1 to Section 6.5.7 present the BC alert models and thresholds for identifying brake temperature scenarios that do not comply with the TS TOC.1 requirements and for identifying brake cut-outs.

6.5.1. Types of alerts

BC alert 1 to alert 4 shall only trigger once each per train pass (see the following):

1. BC alert 1 – refers to freight trains with BC >10%
2. BC alert 2 – refers to freight trains with BC in the last three vehicles
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 preceding BC alert types terminology shall be used to refer to the respective defective brake conditions in TS TOC.1.

BC alert 5 and alert 6 shall trigger once per bogie or vehicle that satisfies the respective BC model (see the following):

5. BC alert 5 – refers to a bogie with brakes cut-out or inoperative
6. BC alert 6 – refers to a vehicle with brakes cut-out or inoperative

BC alerts shall be prioritised in the following order, from highest to lowest:

(Highest) BC2 → BC1 → BC3 → BC4 → BC6 → BC5 (Lowest)

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 following condition is satisfied.

$(N_{CW} / N_W) > 0.10$

and

$T_{ARWV} \leq 50$

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)

T_{ARWV} = average relative temperature of all the wheels on the vehicles which have all wheels cold (administrator configurable)

6.5.3. Model BC2 - freight last three vehicles

This model shall determine if the brakes are cut-out on any of the last three vehicles in a freight train (including locomotives). The alert is triggered if any of the last three vehicles 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 following condition is satisfied.

$(N_{CC} / N_C) > 0.125$

and

$T_{ARWV} \leq 50$

Where:

N_{CC} = number of carriages with all wheels triggering cold wheel alerts

N_C = total number of carriages in the train

T_{ARWV} = average relative temperature of all the wheels on the vehicles which have all wheels cold (administrator configurable)

6.5.5. Model BC4 - passenger terminal end

This model shall determine if the brakes are cut-out or inoperative 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 and T_{ARWV} on each vehicle is less than or equal to 50. The model shall produce only BC alerts.

6.5.6. Model BC5 – bogie cut-out

This model shall determine if the brakes are cut-out or inoperative on a bogie. The alert is triggered if CWD alerts are detected on all wheels on a bogie and T_{ARWB} on each bogie is less than or equal to 50. The model shall produce only BC alerts.

6.5.7. Model BC6 – vehicle cut-out

This model shall determine if the brakes are cut-out or inoperative on a vehicle. The alert is triggered if CWD alerts are detected on all wheels on a vehicle and T_{ARWV} on each vehicle is less than 50. 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 thresholds shown in Table 10 excludes 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 covered in the remainder of this section is based on the recommendation from Sydney Trains.

Exception conditions are as follows:

a. at all wheel positions where the maximum absolute wheel temperature threshold ($E1_{AW}$) has been exceeded bearing alarm or alert models P2, F2, P3 and F3 shall be disabled

b. for remaining bearing alarm models P1 and F1 the absolute temperature thresholds shall be changed to the values shown in Table 10 according to the maximum absolute wheel temperature of the wheel at the same location

c. the disabling of alarm models and the modification of alarm model thresholds 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 F1 S_{AB} according to $E1_{AW}$

Level	$E1_{AW}$ (°C)	Model P1 S_{ABW} (°C)	Model P1 S_{ABH} (°C)	Model P1 S_{ABE} (°C)	Model F1 S_{ABW} (°C)	Model F1 S_{ABH} (°C)	Model F1 S_{ABE} (°C)
3	290	105	115	145	105	115	145
2	250	100	110	140	100	110	140
1	210	95	105	135	95	105	135

All 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. Stopping a train for inspection under this scenario provides no benefit to TfNSW or the train operator and only results in network delays and confusion. The model and parameters shown in the remainder of this section prevent wheel alarms and alerts being triggered when the train is detected as decelerating at a rate greater than the specified threshold.

Exception conditions are as follows:

a. the deceleration rate shall be calculated between every axle based on the individual axle speeds

b. 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 and cold wheel alerts shall be disabled

c. all X_W thresholds shall remain as specified in Section 6.3

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

	S_{RW1} (°C) DR > 0.3 m/s^2	S_{RW1} (°C) DR > 0.6 m/s^2	S_{RW2} (°C) DR > 0.3 m/s^2	S_{RW2} (°C) DR > 0.6 m/s^2
High wheel alarm	300	330	380	410
Medium wheel alarm	240	270	300	330
Low wheel alarm	190	220	0 - disabled	0 - disabled

Each of the DR thresholds and the exception thresholds shall be administrator configurable.

8. Other exceptions and functionalities

The exceptions and functionalities covered in Section 8.1 to Section 8.3 may be considered to provide flexibility in the operation of the BBT systems to manage false alarms and support rail network operations. All permanent changes requiring changes to Appendix A shall be submitted to TfNSW's Asset Management Branch for inclusion into the next version.

8.1. Suppression of low hot wheel alarms

Where nuisance low hot wheel alarms are being observed at specific sites due to the application of brakes by rolling stock near or through the site, the suppression of the low hot wheel alarms is permitted.

8.2. Escalation of low hot wheel alarms to medium hot wheel alarms

Low hot wheel alarms may be escalated to medium hot wheel alarms at specific sites in order for rolling stock triggering the low hot wheel alarms to be stopped sooner. For example, where there is evidence that rolling stock triggering the low hot wheel alarms are likely to trigger medium or high hot wheel alarms further down the line, escalating the low hot wheel alarms to medium will enable rolling stock to be stopped sooner, perhaps at an area that is more operationally flexible and of less impact to network performance.

8.3. Local adjustments to alarm thresholds

A risk assessment shall be conducted on any local or site-specific adjustments to alarm thresholds and the result reported to TfNSW's Asset Management Branch.

Changes to alarm thresholds are permitted where there is no detrimental impact to safety and operational risk. For example, local or site-specific adjustments to hot wheel alarm thresholds are permitted provided it has no safety or operational risk impact.

Where local or site-specific adjustments to alarm thresholds are to be made permanent, the changes shall be reported to TfNSW's Asset Management Branch to ensure that Appendix A is updated accordingly.

Appendix A BBT site-specific thresholds

This appendix covers BBT site-specific thresholds. Site-specific thresholds are included for:

- Table 12 – Springwood Up
- Table 13 – Engadine Up
- Table 14 – Wyee Up and Down
- Table 15 – Rhodes Down
- Table 16 – Rhodes Up

Table 12 – Springwood Up site-specific thresholds

Model	Parameter	Default threshold	Site-specific threshold
Bearing model P1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	150	
	S_{HIGH}	151	
Bearing model P2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model P3	S_{ADB1} (medium alert)	27	
	S_{ADB1} (low alert)	15	
	S_{ADB2} (medium alert)	30	
	S_{ADB2} (low alert)	30	
Bearing model F1	S_{ABE} (extreme alarm)	130	135
	S_{ABH} (hot alarm)	100	105
	S_{ABW} (warm alarm)	90	95
	S_{LOW}	20	
	S_{HIGH}	30	
Bearing model F2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model F3	S_{ADB1} (medium alert)	37	
	S_{ADB1} (low alert)	25	
	S_{ADB2} (medium alert)	40	
	S_{ADB2} (low alert)	40	
Hot wheel models	S_{RW1} (high alarm)	270	
	S_{RW1} (medium alarm)	210	
	S_{RW1} (low alarm)	160	180

Model	Parameter	Default threshold	Site-specific threshold
	S_{RW2} (high alarm)	350	410
	S_{RW2} (medium alarm)	270	330
	S_{RW2} (low alarm)	0 - disabled	
	X_W (high alarm)	3.5	
	X_W (medium alarm)	2.6	
	X_W (low alarm)	2	2.2
Exception model E1 (for P1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E1 (for F1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	150
	Level 3 – S_{ABH}	115	120
	Level 3 – S_{ABW}	105	110
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	145
	Level 2 – S_{ABH}	110	115
	Level 2 – S_{ABW}	100	105
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	140
	Level 1 – S_{ABH}	105	110
	Level 1 – S_{ABW}	95	100
Exception model E2	$S_{RW}1$ (high alarm) - DR1	300	
	$S_{RW}1$ (medium alarm) - DR1	240	
	$S_{RW}1$ (low alarm) - DR1	190	
	$S_{RW}2$ (high alarm) - DR1	380	430
	$S_{RW}2$ (medium alarm) - DR1	300	350
	$S_{RW}2$ (low alarm) - DR1	0 - disabled	

Model	Parameter	Default threshold	Site-specific threshold
	$S_{RW}1$ (high alarm) - DR2	330	
	$S_{RW}1$ (medium alarm) - DR2	270	
	$S_{RW}1$ (low alarm) - DR2	220	
	$S_{RW}2$ (high alarm) - DR2	410	430
	$S_{RW}2$ (medium alarm) - DR2	330	350
	$S_{RW}2$ (low alarm) - DR2	0 - disabled	
	DR1	0.3	
	DR2	0.6	
Cold wheel alert models (generic)	Algor. 1 active	yes	
	Algor. 2 active	yes	
	CWT1	25	
	CWT2	10	
	CWT3	25	
	Min C_{AV}	30	
	Alpha (α)	1.3	

Table 13 – Engadine Up site-specific thresholds

Model	Parameter	Default threshold	Site-specific threshold
Bearing model P1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	150	
	S_{HIGH}	151	
Bearing model P2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model P3	S_{ADB1} (medium alert)	27	
	S_{ADB1} (low alert)	15	
	S_{ADB2} (medium alert)	30	
	S_{ADB2} (low alert)	30	
Bearing model F1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	20	
	S_{HIGH}	30	
Bearing model F2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	

Model	Parameter	Default threshold	Site-specific threshold
Bearing model F3	S_{ADB1} (medium alert)	37	
	S_{ADB1} (low alert)	25	
	S_{ADB2} (medium alert)	40	
	S_{ADB2} (low alert)	40	
Hot wheel models	S_{RW1} (high alarm)	270	
	S_{RW1} (medium alarm)	210	
	S_{RW1} (low alarm)	160	0 (only RailCorp passenger vehicles)
	S_{RW2} (high alarm)	350	
	S_{RW2} (medium alarm)	270	
	S_{RW2} (low alarm)	0 - disabled	
	X_W (high alarm)	3.5	
	X_W (medium alarm)	2.6	
	X_W (low alarm)	2	2.2
Exception model E1 (for P1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E1 (for F1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E2	$S_{RW}1$ (high alarm) - DR1	300	

Model	Parameter	Default threshold	Site-specific threshold
	$S_{RW}1$ (medium alarm) - DR1	240	
	$S_{RW}1$ (low alarm) - DR1	190	220
	$S_{RW}2$ (high alarm) - DR1	380	
	$S_{RW}2$ (medium alarm) - DR1	300	
	$S_{RW}2$ (low alarm) - DR1	0 - disabled	
	$S_{RW}1$ (high alarm) - DR2	330	
	$S_{RW}1$ (medium alarm) - DR2	270	
	$S_{RW}1$ (low alarm) - DR2	220	
	$S_{RW}2$ (high alarm) - DR2	410	
	$S_{RW}2$ (medium alarm) - DR2	330	
	$S_{RW}2$ (low alarm) - DR2	0 - disabled	
	DR1	0.3	0.2
	DR2	0.6	
Cold wheel alert models (generic)	Algor. 1 active	yes	
	Algor. 2 active	yes	
	CWT1	25	
	CWT2	10	
	CWT3	25	
	Min C_{AV}	30	
	Alpha (α)	1.3	

Table 14 – Wyee Up and Down site-specific thresholds

Model	Parameter	Default threshold	Site-specific threshold
Bearing model P1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	150	20
	S_{HIGH}	151	30
Bearing model P2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model P3	S_{ADB1} (medium alert)	27	
	S_{ADB1} (low alert)	15	
	S_{ADB2} (medium alert)	30	
	S_{ADB2} (low alert)	30	
Bearing model F1	S_{ABE} (extreme alarm)	130	

Model	Parameter	Default threshold	Site-specific threshold
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	20	
	S_{HIGH}	30	
Bearing model F2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model F3	S_{ADB1} (medium alert)	37	
	S_{ADB1} (low alert)	25	
	S_{ADB2} (medium alert)	40	
	S_{ADB2} (low alert)	40	
Hot wheel models	S_{RW1} (high alarm)	270	
	S_{RW1} (medium alarm)	210	
	S_{RW1} (low alarm)	160	
	S_{RW2} (high alarm)	350	
	S_{RW2} (medium alarm)	270	
	S_{RW2} (low alarm)	0 - disabled	
	X_W (high alarm)	3.5	
	X_W (medium alarm)	2.6	
	X_W (low alarm)	2	
Exception model E1 (for P1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E1 (for F1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	

Model	Parameter	Default threshold	Site-specific threshold
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E2	$S_{RW}1$ (high alarm) - DR1	300	
	$S_{RW}1$ (medium alarm) - DR1	240	
	$S_{RW}1$ (low alarm) - DR1	190	
	$S_{RW}2$ (high alarm) - DR1	380	
	$S_{RW}2$ (medium alarm) - DR1	300	
	$S_{RW}2$ (low alarm) - DR1	0 - disabled	
	$S_{RW}1$ (high alarm) - DR2	330	
	$S_{RW}1$ (medium alarm) - DR2	270	
	$S_{RW}1$ (low alarm) - DR2	220	
	$S_{RW}2$ (high alarm) - DR2	410	
	$S_{RW}2$ (medium alarm) - DR2	330	
	$S_{RW}2$ (low alarm) - DR2	0 - disabled	
	DR1	0.3	
	DR2	0.6	
Cold wheel alert models (generic)	Algor. 1 active	yes	
	Algor. 2 active	yes	
	CWT1	25	
	CWT2	10	
	CWT3	25	
	Min C_{AV}	30	
	Alpha (α)	1.3	

Table 15 – Rhodes Down site-specific thresholds

Model	Parameter	Default threshold	Site-specific threshold
Bearing model P1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	150	

Model	Parameter	Default threshold	Site-specific threshold
	S_{HIGH}	151	
Bearing model P2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model P3	S_{ADB1} (medium alert)	27	
	S_{ADB1} (low alert)	15	
	S_{ADB2} (medium alert)	30	
	S_{ADB2} (low alert)	30	
Bearing model F1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	20	
	S_{HIGH}	30	
Bearing model F2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	37	
Bearing model F3	S_{ADB1} (medium alert)	30	
	S_{ADB1} (low alert)	40	
	S_{ADB2} (medium alert)	40	
	S_{ADB2} (low alert)	40	
Hot wheel models	S_{RW1} (high alarm)	270	
	S_{RW1} (medium alarm)	210	130
	S_{RW1} (low alarm)	160	0 - disabled
	S_{RW2} (high alarm)	350	
	S_{RW2} (medium alarm)	270	
	S_{RW2} (low alarm)	0 - disabled	
	X_W (high alarm)	3.5	
	X_W (medium alarm)	2.6	2
	X_W (low alarm)	2	0 - disabled
Exception model E1 (for P1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	

Model	Parameter	Default threshold	Site-specific threshold
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E1 (for F1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E2	$S_{RW}1$ (high alarm) - DR1	300	
	$S_{RW}1$ (medium alarm) - DR1	240	
	$S_{RW}1$ (low alarm) - DR1	190	
	$S_{RW}2$ (high alarm) - DR1	380	
	$S_{RW}2$ (medium alarm) - DR1	300	
	$S_{RW}2$ (low alarm) - DR1	0 - disabled	
	$S_{RW}1$ (high alarm) - DR2	330	
	$S_{RW}1$ (medium alarm) - DR2	270	
	$S_{RW}1$ (low alarm) - DR2	220	
	$S_{RW}2$ (high alarm) - DR2	410	
	$S_{RW}2$ (medium alarm) - DR2	330	
	$S_{RW}2$ (low alarm) - DR2	0 - disabled	
	DR1	0.3	
	DR2	0.6	
Cold wheel alert models (generic)	Algor. 1 active	yes	
	Algor. 2 active	yes	
	CWT1	25	
	CWT2	10	
	CWT3	25	
	Min C_{AV}	30	
	Alpha (α)	1.3	

Table 16 – Rhodes Up site-specific thresholds

Model	Parameter	Default threshold	Site-specific threshold
Bearing model P1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	150	
	S_{HIGH}	151	
Bearing model P2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model P3	S_{ADB1} (medium alert)	27	
	S_{ADB1} (low alert)	15	
	S_{ADB2} (medium alert)	30	
	S_{ADB2} (low alert)	30	
Bearing model F1	S_{ABE} (extreme alarm)	130	
	S_{ABH} (hot alarm)	100	
	S_{ABW} (warm alarm)	90	
	S_{LOW}	20	
	S_{HIGH}	30	
Bearing model F2	S_{VDB} (warm alarm)	50	
	S_{VDB} (low alert)	30	
Bearing model F3	S_{ADB1} (medium alert)	37	
	S_{ADB1} (low alert)	25	
	S_{ADB2} (medium alert)	40	
	S_{ADB2} (low alert)	40	
Hot wheel models	S_{RW1} (high alarm)	270	
	S_{RW1} (medium alarm)	210	
	S_{RW1} (low alarm)	160	
	S_{RW2} (high alarm)	350	
	S_{RW2} (medium alarm)	270	
	S_{RW2} (low alarm)	0 - disabled	
	X_W (high alarm)	3.5	
	X_W (medium alarm)	2.6	
	X_W (low alarm)	2	2.2
Exception model E1 (for P1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	

Model	Parameter	Default threshold	Site-specific threshold
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E1 (for F1)	Level 3 – $E1_{AW}$	290	
	Level 3 – S_{ABE}	145	
	Level 3 – S_{ABH}	115	
	Level 3 – S_{ABW}	105	
	Level 2 – $E1_{AW}$	250	
	Level 2 – S_{ABE}	140	
	Level 2 – S_{ABH}	110	
	Level 2 – S_{ABW}	100	
	Level 1 – $E1_{AW}$	210	
	Level 1 – S_{ABE}	135	
	Level 1 – S_{ABH}	105	
	Level 1 – S_{ABW}	95	
Exception model E2	$S_{RW}1$ (high alarm) - DR1	300	
	$S_{RW}1$ (medium alarm) - DR1	240	
	$S_{RW}1$ (low alarm) - DR1	190	0 – disabled (D class vehicle only)
	$S_{RW}2$ (high alarm) - DR1	380	
	$S_{RW}2$ (medium alarm) - DR1	300	
	$S_{RW}2$ (low alarm) - DR1	0 - disabled	
	$S_{RW}1$ (high alarm) - DR2	330	
	$S_{RW}1$ (medium alarm) - DR2	270	300 (D class vehicle only)
	$S_{RW}1$ (low alarm) - DR2	220	0 – disabled (D class vehicle only)
	$S_{RW}2$ (high alarm) - DR2	410	
	$S_{RW}2$ (medium alarm) - DR2	330	360 (D class vehicle only)
	$S_{RW}2$ (low alarm) - DR2	0 - disabled	
	DR1	0.3	0.2

Model	Parameter	Default threshold	Site-specific threshold
	DR2	0.6	0.5
Cold wheel alert models (generic)	Algor. 1 active	yes	
	Algor. 2 active	yes	
	CWT1	25	
	CWT2	10	
	CWT3	25	
	Min C_{AV}	30	
	Alpha (α)	1.3	

Appendix B Graphical representation of HBD alarm and alert models (default thresholds)

This appendix provides graphical representations of HBD alarm and alert models.

Figure 1 is a graphical representation of HBD alarm and alert models P1, F1, P2, and F2 (default thresholds).

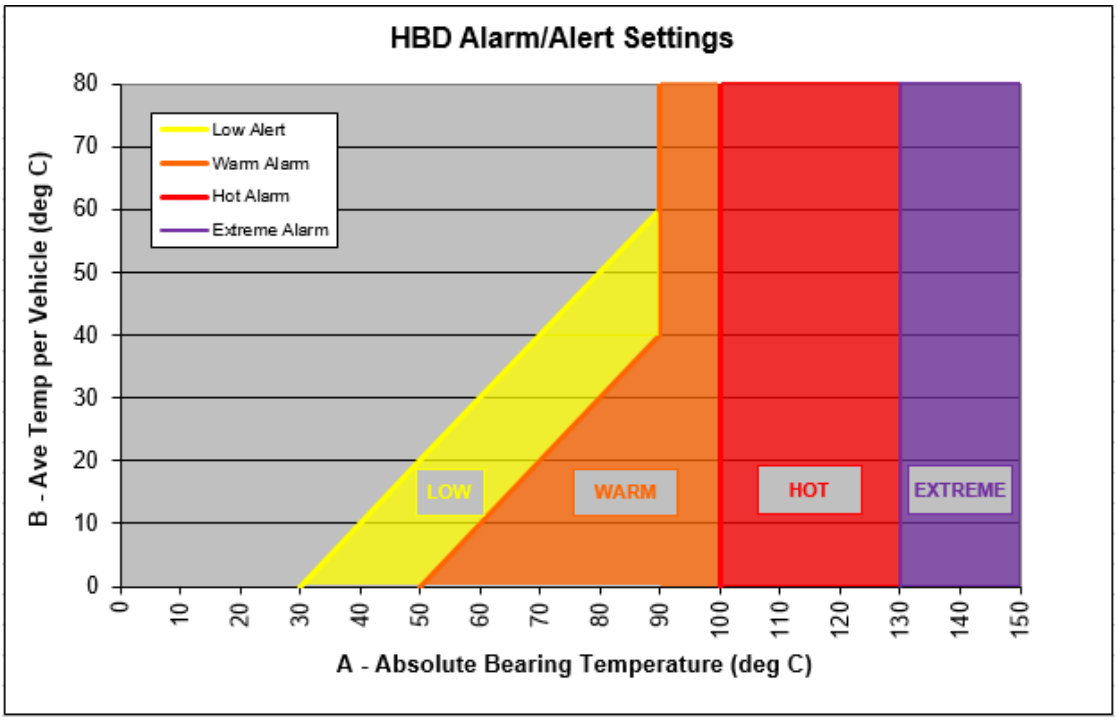

Figure 1 – HBD alarm and alert models P1, F1, P2, and F2

Figure 2 is a graphical representation of HBD alarm model P1 and F1 (default thresholds for F1).

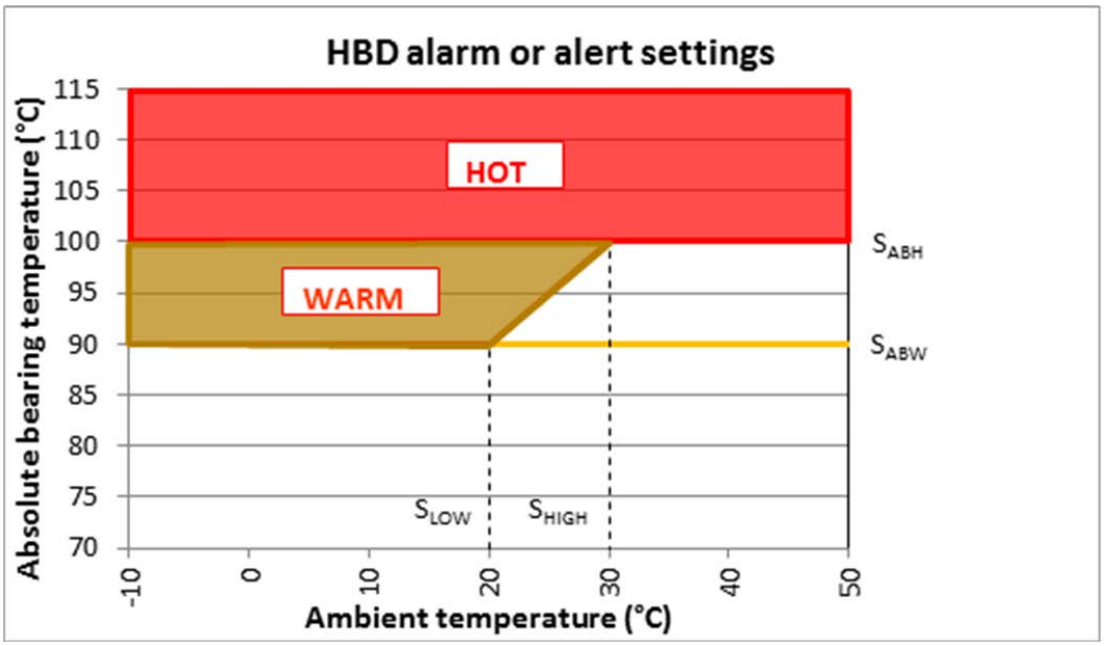

Figure 2 – HBD alarm model P1 and F1

Appendix C Graphical representation of HWD alarm model (default thresholds)

This appendix provides a graphical representation of an HWD alarm model.

Figure 3 is a graphical representation of HWD alarm model (default thresholds).

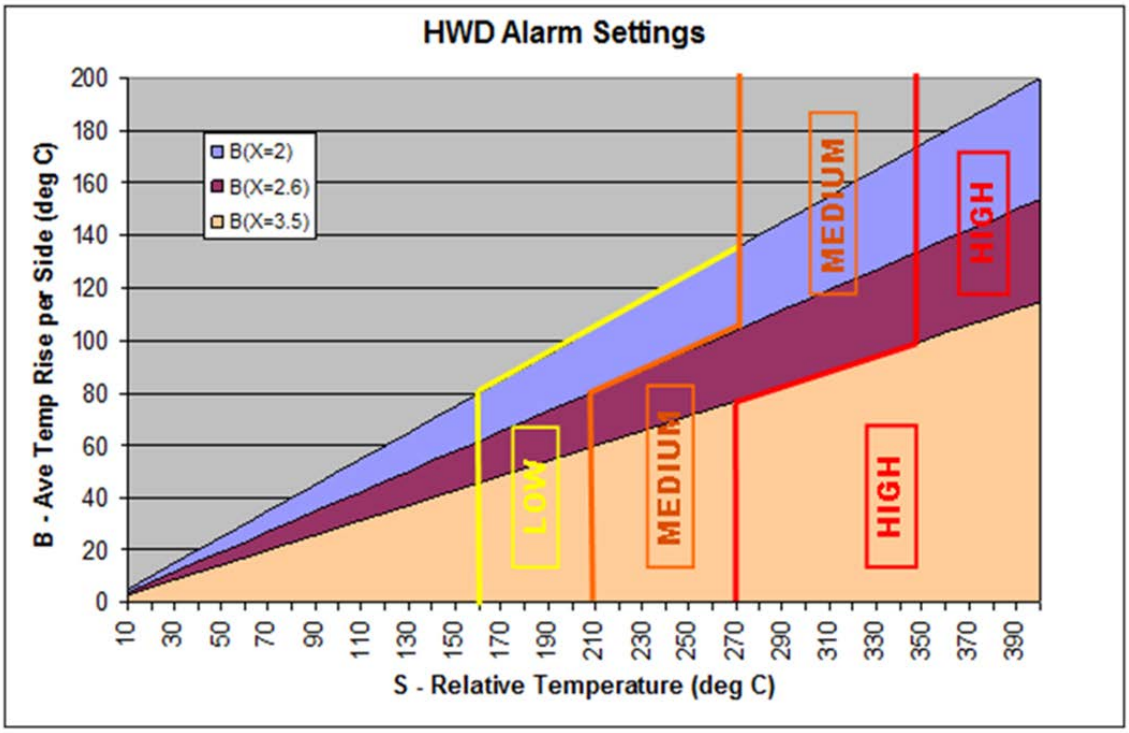

Figure 3 – HWD alarm model