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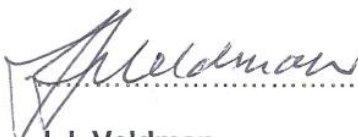

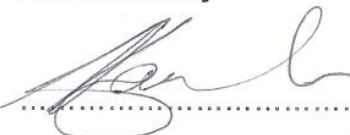
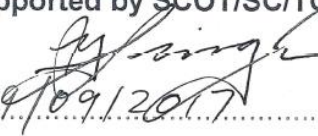
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1. INTRODUCTION

Adequate boiler protection is essential to safeguard human life, the plant and to prevent major damage and shall always be available on demand. However, the benefits of such protection notwithstanding the importance of safeguarding human life must be balanced against the inevitable reduction in reliability associated with the protection equipment and systems. This Standard strives to achieve such a balance, and to ensure the documentation and control of the protection requirements and settings at each relevant Eskom fossil fuel fired Power Station (PS).

The document content has been compiled jointly by a working group of boiler and C&I engineers from Group Technology and input from representative PS's, incorporating recommendations from the 1999 Plant Reliability Study and the consideration of protection philosophies and systems already existing on respective fossil fuel fired boilers.

2. SUPPORTING CLAUSES

2.1 SCOPE

This document covers the minimum protection functions required for the safe, efficient and reliable operation of fossil fuel fired boilers during both normal and transient plant conditions.

The document further covers the testing requirements to ensure that the boiler protection systems installed are managed such that the integrity of the equipment is ensured, and that it is available on demand.

2.1.1 Purpose

The purpose of this document is to prevent loss of life or major plant damage by ensuring that fossil fuel fired boilers are not operated beyond safe limits. This is achieved by:

- Defining the minimum protection functions for all fossil fuel fired boilers.
- Ensuring that each Power Station has a protection function philosophy document detailing the specific plant protection functions, setting values and testing requirements.

The protection functions as defined in this document should be supplemented by appropriate control set-points, process limiters, alarms, sequential tripping schemes, automatic load reduction and/or manual operator interventions.

2.1.2 Applicability

This standard shall apply to all fossil fuel fired boilers.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

- [1] 240 - 105453648: Fossil Fuel Firing Regulation Standard.
- [2] 240 - 109253238: C&I Protection Systems Redundancy and Voting Guideline
- [3] 240 - 83338028: Operating and Maintenance Strategy for C&I Safety Instrumented Systems Guideline.
- [4] 240 - 105249370: Operating and Maintenance Requirements for Coal Fired Boiler Flame Failure Protection Devices Standard.
- [5] 240 - 83459207: Safe Operation and Maintenance of Submerged Scraper Conveyors Standard.
- [6] 240 - 53114002: Engineering Change Management Procedure.

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2.2.2 Informative

- [7] VGB-R 117 C: Guideline for Power Plant Equipment Protection.
- [8] VGB-S-008-S-00-2011-03-EN: Recommendation for SIL Classification of Safety Related Systems in Steam Boiler Systems and Systems in the Water Circuit.
- [9] IEC 61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems.
- [10] IEC 61511: Functional Safety Instrumented Systems for the Process Industry Sector.
- [11] Chambers Dictionary of Science and Technology 2007 edition, ISBN - 13:978 0550100719.

2.3 DEFINITIONS

Definition	Description
Boiler Master Fuel Trip	Boiler master fuel trip means a device which will, either automatically or by means of a manual push button, stop all fuel input into a boiler furnace.
Exemption	Exemption means permission of a temporary nature to be excused from a provision of this standard.
Fail Safe	A design in which power supply, control or structure is able to return to a safe condition in the event of failure or mal-operation, by automatic operation of protective devices or otherwise.
Flame	Flame means the visible evidence of the combustion process.
Furnace Flame Failure Protection	Furnace flame failure protection means a system consisting of a series of flame monitors or flame scanners to detect a stable flame and protect the furnace in the event that the flame becomes unstable or on a loss of ignition. The flame monitor/scanner information may also be used to determine the stability of the combustion.
Protection functions	All those functions that will trip the boiler or initiate actions to prevent major boiler damage, in the event of a predetermined process level being exceeded in terms of the plants defined operating envelope.
Total Combustion Air	Means the measured stoichiometric air and excess air required to achieve complete combustion and supplied through the burners including the over fire air and/or side wall air, but excluding tramp air.
Waiver	A waiver means permission of a permanent nature to be excused from a provision of this standard

2.3.1 Disclosure Classification

Controlled Disclosure: Controlled Disclosure to External Parties, either enforced by law, or discretionary

2.4 ABBREVIATIONS

Abbreviation	Description
BMFT	Boiler Master Fuel Trip
C&I	Control and Instrumentation
COE	Centre Of Excellence

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Abbreviation	Description
ECM	Engineering Change Management
FD	Force Draught
FFP	Fabric Filter Plant
FFFR	Fossil Fuel Firing Regulation
HP	High Pressure
ID	Induced Draught
LH	Left Hand
OEM	Original Equipment Manufacturer
OON	Out Of Normal
PEIC	Plant Engineering Integration Coal
PS	Power Station
PSM	Power Station Manager
RH	Right Hand
S&I	Sustainability and Innovation
SSC	Submerge Scraper Conveyor
TOI	Temporary Operating Instruction

2.5 ROLES AND RESPONSIBILITIES

Each Power Station shall develop and implement the requirements described in this Standard to ensure that the fossil fuel fired boiler protection systems installed are managed such that the integrity of the equipment is ensured, and that it is available on demand to prevent major plant damage and loss of human life.

The Power Station Manager/General Manager is accountable for ensuring that this Standard is implemented and that the Power Station fully complies with the Standard.

The Station Engineering Manager is responsible for ensuring that the technical content and engineering requirements of this Standard are complied with through the development and implementation of a station specific boiler protection function philosophy document.

The Station Maintenance Manager is responsible for ensuring that the appropriate inspection and testing of the boiler protection system as defined in the station specific boiler protection function philosophy document is complied with, including the record keeping there-off.

The Station Operating Manager is responsible for ensuring that the plant is operated within the boiler protection envelope and testing requirements are executed as defined in the Station specific boiler protection function philosophy document.

PEIC is responsible for assisting the respective Stations and COE with the development of appropriate protection function philosophies for those protection functions specified in the Standard in respect of which the Station does not comply.

COE as design authority is responsible through the ECM process for the design of those protection functions specified in the Standard that a Station does not comply with, or any changes to the existing protection functions as implemented at a Station.

2.6 PROCESS FOR MONITORING

Compliance monitoring to this Standard will be via assurance reviews and audits.

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2.7 RELATED/SUPPORTING DOCUMENTS

The following documentation shall be produced as a result of this Standard;

- The relevant PS shall compile a boiler protection function philosophy document as required.
- The relevant PS shall compile inspection and test work instructions as required.
- The relevant PS shall maintain records that certify that proof tests and inspections were completed as required.

3. REQUIREMENTS

3.1 BOILER PROTECTION PHILOSOPHY DOCUMENT

Each relevant Power Station shall compile and maintain a boiler protection function philosophy document with the following content.

3.1.1 Front Cover

The cover shall include,

- The name of the Power Station.
- The relevant units at the Power Station. Where boilers on the same Power Station incorporate different protection philosophies, a separate document shall be compiled and authorised for each group of boilers. Where boilers use different trip limit values for the same protection function both shall be specified and highlighted in the document.
- Registered document number.
- Revision status of the document.
- Signatures as follows;
 - Compiler: Knowledgeable person on the applied boiler protection philosophy
 - Functional Responsibility: Boiler Engineering Manager
 - Approval: Station Engineering Manager
 - Authorisation: Senior Manager, PEIC

3.1.2 Protection Functions Implemented at the Subject PS

This section shall include all installed protection functions, which include the following information per protection function;

- Protection function description.
- Alarm and trip limit values, including any time delays applied.
- Testing requirements and frequency, both on- and off-load where applicable.
- Brief summary of the protection logic formation, actions initiated and degree of redundancy used to implement the protection function.
- Test analysis, reporting and recording requirements.

The section may be in the format of tables, functional logic diagrams, descriptive text or any other suitable means to adequately display the necessary information.

3.1.3 Plant Information

Supporting information, for example OEM descriptions, drawings and other information may at the discretion of the PS be attached to the document as an Appendix.

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3.2 BOILER PROTECTION PHILOSOPHY DOCUMENT CONTROL

- The boiler protection function philosophy document shall be compiled by the relevant PS Engineering department, approved by the PS Engineering Manager and authorised by the Senior Manager PEIC.
- Engineering changes to the PS boiler protection function philosophy, alarm and trip limit values, including time delay changes contained in the document shall originate, be classified and tracked through the ECM process.
- The alarm and trip limit values, protection function mechanisms and levels of redundancy initially entered in the document shall be those defined in the plant Operating Technical Specification and existing on the plant at the time of compiling the boiler protection function philosophy document. Any engineering change to these shall be processed only after authorisation of the initial document, through the above defined process.
- There may be individual isolated cases where existing plant do not require the stipulated protection function due to specific design characteristics. In this case the relevant PS Engineering Manager shall provide written motivation for non-compliance to the Senior Manager PEIC. This will then be reviewed and authorised by the Senior Manager PEIC by means of a waiver.
- Where modification to existing equipment is required to meet the requirements of this Standard, a programme for implementation will be agreed between the Senior Manager PEIC and the relevant PS Engineering Manager. The Senior Manager PEIC will issue an exemption for compliance as per the agreed programme.
- Where protection function non-compliances are covered by approved FFFR waivers and exemptions, the application for waivers and exemptions under this Standard is not required. Copies of the same should however be attached as an Appendix to the PS specific boiler protection function philosophy document
- It is recommended that waivers and exemptions be managed and controlled by attaching signed copies there-off as an Appendix to the PS specific boiler protection function philosophy document.

3.3 GENERAL MANAGEMENT PRINCIPLES

With the new standards on functional safety on the basis of EN 61508 and EN 61511, functional safety management has been introduced for the equipment requirements in boiler protection systems. As these standards provide considerable scope for discretionary judgement by manufactures and operators it is necessary to establish firm recommendations for the application of these standards in the design of boiler protection systems. The aim of this Standard is to provide such assistance and in this context, it is incumbent upon all to integrate the requirements of this Standard into the design process of boiler protection systems.

The boiler protection system, as a minimum shall be a fail-safe multi-channel system. The system shall be capable of implementing protection functions up to a Safety Integrity Level 3 classification in accordance with the requirements of functional safety standards. The protection system shall accept plant protection input signals in a 2oo3, 2oo2, 1oo2 or 1oo1 selection configuration, depending on the measurement loop installation constraints and criticality requirements.

The boiler protection system is interfaced with the unit control and automation system and signal exchange from and to it shall be redundant. In the event of this interface not being able to handle time critical signals, it shall be hardwired.

Each protection function listed in this Standard shall incorporate predetermined values for alarm and boiler trip value limits. The alarm limit values should be set such that the warning functions shall direct the operator's attention towards the boiler condition requiring timely assessment and response. The following alarm management principles should be followed:

- Each alarm shall alert, inform and guide the operator.
- Every alarm shall have a defined response (alarm response procedure).

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- Every alarm presented to the operator shall be useful and relevant to the operator.
- Adequate time shall be available for the operator to carry out the defined alarm response.

It is important to note that the boiler shall always be tripped directly via the boiler master fuel trip (BMFT). This operation ensures that the fuel supply to the boiler has been effectively isolated and prevents the possibility of disastrous furnace conditions. Each source of operation of the boiler master fuel trip shall actuate a "cause of trip" indication that informs the operator of the initiating cause of the tripping impulse.

All protection functions shall have documented work instructions for inspection and testing. These work instructions shall be used as a framework within which each Power Station shall establish inspection and test plans, which must take local conditions and equipment technologies into account.

3.4 PROTECTION FUNCTIONS

The following represents the minimum protection functions for fossil fuel fired boilers. It further provides supportive information by capturing the intent and requirement of the respective protection functions;

3.4.1 Direct Boiler Trips Functions

3.4.1.1 Boiler emergency push button;

Intent: The boiler emergency push button enables the operator to trip the boiler at his/her discretion.

Requirement: The boiler emergency pushbutton initiates the boiler master fuel trip. The function should be readily accessible and easily identified in the control room, with protection to prevent inadvertent operation but allow easy operation when necessary.

3.4.1.2 Oil burner flame failure protection;

Intent: To protect the boiler against furnace explosions in the event of a loss of ignition.

Requirement: Boiler master fuel trip initiates when loss of ignition occurs on all the oil burners, unless the furnace flame failure protection is armed.

3.4.1.3 Furnace flame failure protection;

Intent: To protect the boiler against furnace explosions in the event that the flame becomes unstable or on the loss of ignition.

Requirement: Boiler master fuel trip initiates under the following conditions;

- a) When the required number of flame monitors dictated by the tripping logic, detect that ignition has been lost or is in danger of being lost, via the tripping of the mill(s) in service.
- b) When flame failure has occurred in one half of a twin or split furnace.

3.4.1.4 Both ID fans off;

Intent: To protect the furnace from over pressure due to a total loss of flue gas extraction.

Requirement: Boiler master fuel trip, which shall stop all fuel input into the boiler furnace, and trip the FD fans immediately.

3.4.1.5 Both FD fans off;

Intent: To protect the furnace due to the total loss of air for combustion and the associated risk of a furnace explosion.

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Requirement: Boiler master fuel trip, which shall stop all fuel input into the boiler furnace and trip the ID fans immediately.

3.4.1.6 Furnace pressure >maximum (Positive pressure);

Intent 1: To protect the furnace from structural damage and possible injury to personnel in the event of unstable combustion.

Requirement 1: Boiler master fuel trip, which stops all fuel input into the boiler furnace.

Intent 2: To protect the furnace from structural damage and possible injury to personnel in the event of draught group imbalance.

Requirement 2: If furnace pressure increases beyond the maximum allowable furnace pressure, trip the draught groups.

Note: The actual protection value could be the same for requirement (1) and (2) depending on the design values.

3.4.1.7 Furnace pressure < minimum (Negative pressure);

Intent 1: To protect the furnace from structural damage and possible injury to personnel in the event of unstable combustion.

Requirement 1: Boiler master fuel trip, which stops all fuel input into the boiler furnace.

Intent 2: To protect the furnace from structural damage and possible injury to personnel in the event of draught group imbalance.

Requirement 2: If furnace pressure decreases beyond the maximum allowable furnace negative pressure, trip the draught groups.

Note: The actual protection value could be the same for requirement (1) and (2) depending on the design values.

3.4.1.8 Boiler total combustion air flow < minimum;

Intent: Prevent boiler furnace explosions.

Requirement: Boiler master fuel trip at 5% below minimum purge air flow limitation.

3.4.1.9 Drum level > maximum (Drum boilers only);

Intent: To prevent water carry over into the super-heaters.

Requirement 1: With boiler fires in trip the boiler master fuel trip on high drum level.

Requirement 2: With boiler fires out trip the feedwater pumps on high drum level.

3.4.1.10 Drum level < minimum (Drum boilers only);

Intent: To prevent short term overheating of water-wall tubes.

Requirement: Boiler master fuel trip at low drum level.

3.4.1.11 Inadequate water wall circulation (Forced or assisted circulation boilers only);

Intent: To protect the boiler water-wall tubes from over-heating.

Requirement: Boiler master fuel trip at no or low flow conditions.

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3.4.1.12 Economiser inlet or evaporator flow < minimum (Benson boilers only);

Intent: To protect the economiser and evaporator tubes from over-heating.

Requirement: Boiler master fuel trip at minimum flow limit.

3.4.1.13 Attemperator 1.1 or Evaporator outlet steam temperature > maximum (Benson boilers only);

Intent: To protect the evaporator tubes and outlet headers from overheating.

Requirement: Boiler trip at maximum allowable operating temperature.

3.4.1.14 HP Bypass outlet steam temperature > maximum:

Intent: To protect the HP bypass discharge and cold reheat pipe work up to the reheater inlet header from overheating.

Requirement:

- a) Boiler master fuel trip at maximum allowable outlet temperature. (Boilers where the HP Bypass performs a boiler safety function).
- b) HP Bypass trip closed at maximum allowable outlet temperature (Boilers equipped with boiler safety valves).

3.4.1.15 No or Low boiler steam flow path protection;

Intent: To protect the superheater and reheater tubing from short term overheating in the entire circuit or part there-of.

Requirement: Boiler master fuel trip if no or low steam flow path condition exists.

3.4.1.16 Boiler protection system fault;

Intent: Prevent boiler operation without the protection system available.

Requirement: Boiler master fuel trip on a loss of the protection system.

3.4.2 Time Dependant Boiler Trip Functions (Could be supported or even averted by the use of other interventions such as mill tripping and or boiler run back)**3.4.2.1 Superheater outlet steam temperature > maximum;**

Intent: To protect the thick wall components and steam piping systems against overheating.

Requirement: Boiler trip when maximum permissible superheater outlet steam temperature is exceeded.

Note: Maximum permissible steam temperature trip is configured as a time/temperature dependent trip. This could be supported by earlier tripping of mills, manual or automatic boiler runback to prevent the trip from actuating.

3.4.2.2 Reheater outlet steam temperature > maximum

Intent: To protect the thick wall components and steam piping systems against overheating.

Requirement: Boiler trip when maximum permissible reheater outlet steam temperature is exceeded.

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Note: Maximum permissible steam temperature trip is configured as a time/temperature dependent trip. This could be supported by earlier tripping of mills, manual or automatic boiler runback to prevent the trip from actuating.

3.4.2.3 FFP inlet temperature > maximum (Stations with FFP plants only);

Intent: Prevent FFP bag damage during high boiler gas outlet temperature operation.

Requirement: Boiler trip on high FFP inlet temperature.

Note: Maximum permissible inlet temperature trip in some cases could be supported by the earlier boiler runback to prevent the trip from actuating.

3.4.2.4 SSC Backlog exceeded (Boilers with SSC's only);

Intent: To prevent a hazardous situation at the SSC due to the accumulation of hot, unquenched bottom ash.

Requirement: Boiler trip at sustained unavailability of SSC and maximum backlog exceeded.

Note: Maximum permissible backlog trip that is supported by the earlier boiler runback to prevent the trip from actuating.

3.5 TESTING

3.5.1 PROOF TESTING AND INSPECTION

The relevant PS shall prepare and implement an inspection and testing plan for the routine testing of the boiler protection system and respective protection functions, such that it cover the following aspects;

- **On load testing:** Testing of individual furnace flame failure protection equipment to prove its operational integrity as defined in the FFFR.
- **Full functional trip testing of the boiler master fuel trip:** Full functional trip proof testing of all mill groups and the boiler master fuel trip from the furnace flame failure protection equipment as defined in the FFFR.
- **Validation of the alarm and trip devices and settings:** Alarm and trip value settings and device calibration shall be validated as part of the off load simulated functional tests.
- **Off load simulated functional testing:** A off load simulated functional test shall be performed as part of the re-commissioning of the protection system after a major outage or modification or repair to all or part of the boiler protection system. In addition to the simulated functional test, a functional trip test of the boiler master fuel trip shall be performed before permission is given for fires in. The periodicity of such tests shall however not exceed six years.
- **Inspections:** The boiler protection system and devices shall be periodically visually inspected to ensure the integrity of the system and that there are no simulations, unauthorised modifications and no observable deterioration (for example, missing bolts or instrument covers, rusted brackets, open wires, broken conduits and missing insulation).

Guidance in terms of the maintenance requirements for the boiler protection system is provided in the following governance documents;

- a) 240 - 105249370: Operating and Maintenance Requirements for Coal Fired Boiler Flame Failure Protection Devices Standard.
- b) 240 - 83338028: Operating and Maintenance Strategy for C&I Safety Instrumented Systems Guideline.

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3.6 TESTING RECORDS

The relevant PS shall maintain records in the Maintenance Management System (MMS) that records that proof tests and inspections were completed as required. These records shall include the following information as a minimum;

- Description of the test and/or inspection performed.
- Date the test and/or inspection was performed.
- Name of the person(s) who performed the test and/or inspections.
- The plant code of the loop or system tested.
- Results of the test and/or inspection.
- Acceptance or rejection of the test and/or inspection.

All test records shall be signed and archived for legal and record purposes.

4. AUTHORISATION

This document has been seen and accepted by:

Name and Surname	Designation
All	All Power Station/General Managers
All	All Power Station Engineering Managers
Yokesh Singh	Senior Manager PEIC (Acting)
Balin Naicker	Senior Manager PEIC Boilers
Leon van Wyk	Manager Boiler Plant

5. REVISIONS

Date	Rev.	Compiler	Remarks
April 2010	0	DC van Wyk	Defined the minimum boiler protection requirements for fossil fired boilers in Eskom.
November 2012	0.0	DC van Wyk	Draft document for review created from 36-486
February 2013	1	DC van Wyk	Final document for signature.
April 2017	1.1	JJ Veldman	Changes introduced resulted from the 2016 PEIC Assurance Review.
May 2017	1.2	JJ Veldman	Changes introduced resulted from Boiler Study Committee and Boiler Process Care Group.
May 2017	1.3	JJ Veldman	Final Draft document for SC voting
May 2017	1.4	JJ Veldman	Final Draft Document for Formal Comments Review Process
July 2017	1.5	JJ Veldman	Final Draft Document following Formal Review Process
July 2017	1	JJ Veldman	Final Rev 2 Document for Authorisation and Publication

6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Christo van Wyk (Senior Consultant, Combustion).
- Mark Breetzke (Corporate Consultant, Milling & Combustion).
- Sandile Peta (Boiler Plant Engineering).
- Carel Potgieter (Senior Consultant, Process Control).
- Koos Veldman (Senior Consultant, Process Control).

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- Nerino Baruffa (Senior Consultant, Process Control).

7. ACKNOWLEDGEMENTS

None

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APPENDIX A: BPS PROTECTION FUNCTION CONFIGURATIONS

Protection Function		Sources for Settings and Philosophy	Remarks
1	Boiler emergency push button	FFFR (240-105453648)	Hardwired multi contact switch.
2	Oil burner flame failure protection	FFFR (240-105453648)	Special requirements for first mill operation and split furnaces
3	Furnace flame failure protection	FFFR (240-105453648)	Minimum of six measurements in a voting arrangement
4	Both ID fans off	FFFR (240-105453648)	ID and FD sequence trip
5	Both FD fans off	FFFR (240-105453648)	ID and FD sequence trip
6	Furnace pressure > maximum (positive)	FFFR (240-105453648)	Voting measurement of both LH and RH side of the furnace
7	Furnace pressure < minimum (negative)	FFFR (240-105453648)	Voting measurement of both LH and RH side of the furnace
8	Drum level > maximum (Drum boilers only)	Follow boiler design code. Trip to feed pumps could be time delayed if fires are out.	Voting measurement of both LH and RH side of the drum
9	Drum level < minimum (Drum boilers only)	Follow boiler design code	Voting measurement of both LH and RH side of the drum
10	Inadequate water wall circulation (Forced or assisted circulation boilers only)	Follow boiler design code	Derived circulation flow failure
11	Economiser inlet or evaporator flow < minimum (Benson boilers only)	S&I calculation and/or OEM minimum flow specification	Voting measurement
12	Attemperator 1.1 or Evaporator outlet steam temp > maximum (Benson boilers only)	S&I calculation and/or OEM minimum flow specification	Voting measurement
13	Boiler total air flow < minimum	FFFR (240-105453648)	5% below minimum purge air flow limitation
14	Boiler protection system fault	System design	To ensure protection system availability.

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Protection Function	Sources for Settings and Philosophy	Remarks
15 HP Bypass outlet steam temperature > maximum (Units with HP Bypass s HP Bypass outlet steam temperature Systems only)	S&I calculation and/or OEM minimum flow specification	Can be configured with a time delay
16 No or Low boiler steam flow path protection	Follow boiler design	Derived or actual no flow path during PF firing operation
17 Superheater outlet steam temperature > maximum	S&I calculation and/or OEM specification	Configured as a time/temperature dependant protection
18 Reheat outlet steam temperature > maximum	S&I calculation and/or OEM specification	Configured as a time/temperature dependant protection
20 SSC Backlog exceeded (Stations with SSC's only)	Standard 240 - 83459207	Maximum permissible backlog trip that is supported by the earlier boiler runback to prevent the trip from actuating.
21 FFP inlet temperature > maximum (Stations with FFP's only)	OEM Specification	Maximum permissible inlet temperature trip in some cases could be supported by the earlier boiler runback to prevent the trip from actuating.

Note: In most cases the settings and philosophies will be those of the relevant OEM at the time of construction. The references in this column provide additional sources of guidance.

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