Eskom	Guideline	Technology

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FIGURES

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1. INTRODUCTION

The intention of this guideline is to provide a consistent approach to the design of the auxiliary and ancillary cooling water systems, to standardise equipment selection and to ensure the correct design documentation is available when needed. When these cooling systems are to be designed for other type of plants guidance in this document can be applied.

The guideline is written with new installations in mind but can also be applied to modifications on existing installations. When applying the guideline to existing installations it is important to understand the design approach used for the existing installations and to select equipment similar to the equipment in the existing installation.

This document assumes that the Stakeholder Requirements Definition (SRD) is completed and will be used as design input.

The requirement of this document is stated in the LPS PCM 240-53458738 Process Control Manual (PCM) for Perform Low Pressure Services Engineering [32]

2. SUPPORTING CLAUSES

2.1 SCOPE

The scope of this document is to guide all persons responsible for the specification, design, and modification of the auxiliary and ancillary cooling water systems for Eskom Holdings.

The following systems are included

- Auxiliary cooling system separate to the main cooling (turbo-generation plant cooling for both open and closed circuit
- Auxiliary Cooling water system using the Main cooling water as open circuit (i.e. Boiler Aux. Cooling) but separate closed circuit to cool auxiliaries
- Stand-alone evaporative cooling water systems for cooling of ancillaries

2.1.1 Purpose

The purpose is to provide guidance to the design of Eskom auxiliary and ancillary cooling water systems. It includes:

- System design
- Equipment selection
- Control philosophies
- Documentation requirements
- End of phase design reviews
- System performance test requirements

2.1.2 Applicability

This document shall apply to all power plants in Eskom Holdings Limited Divisions.

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] 240-50237155 New MV Motor Procurement Standard

[2] 240-54937450 Fire Protection & Life Safety Design Standard

[3] 240-56030537 Specification for centrifugal Pumps

[4] 240-57617975 Procurement of Power Station Low Voltage Electric Motors Specification Standard

[5] Act 85 of 1993 Occupational Health and Safety Act (OHSA)

[6] ASME B31.1, Power Piping;

[7] ASME B31.3, Process Piping;

[8] BS EN 13480, Metallic Industrial piping;

[9] BSEN14015 Specification for the design of site constructed flat bottom tanks

[10] ISO 9001 Quality Management Systems.

[11] SANS 10162, The structural use of steel;

[12] SANS 10329 Design and construction sectional steel tanks

[13] SANS 10400 The Application of National Building Regulations

[14] SANS 1123 Pipe flanges

[15] SANS 2001-DP2, Construction works Part DP2: Medium pressure pipelines;

[16] SANS 53121 Tanks and vessels for use above ground level

[17] SANS 62 Steel pipes Part 1: Pipes suitable for threading and of nominal size not exceeding 150 mm

[18] SANS 719 Electric welded low carbon steel pipes for aqueous fluids (large bore)

2.2.2 Informative

[19] 240-102547991 General Technical Specification for HVAC system

[20] 240-49230030 Reliability Engineering Analysis Guideline

[21] 240-49230046 Failure Mode and Effect Analysis (FMEA) Guideline

[22] 240-49230111 Hazard and Operability Analysis (HAZOP) Guideline

[23] 240-49230148 Maintenance and logistics support design guideline

[24] 240-50056004 Constructability Analysis Guideline

[25] 240-511486 Documents and Record Management

[26] 240-52843929 Engineering Design Process Reference Guideline

[27] 240-52844017 RAM Analysis Guideline

[28] 240-53113685 Design Review Procedure

[29] 240-53113704 Maintenance Engineering Strategy Report Template

[30] 240-53113712 Demineralised Water Production Using Ion Exchange Resins Chemistry Standard

[31] 240-53114002 Engineering Change Management Procedure

[32] 240-53458738 Process Control Manual (PCM) for Perform Low Pressure Services Engineering

[33] 240-53665024, Engineering Quality Manual;

[34] 240-54179170, Classification and Designation of Technical Documentation Standard;

[35] 240-55864764, Chemistry Standard for Potable Water

[36] 240-55864767 Chemistry Guideline for cooling water

[37] 240-55864833 Chemistry for Auxiliary and Ancillary Cooling Water Systems Manual

[38] 240-55864841, Legionella Guideline;

[39] 240-56355466 Alarm Management System Guideline

[40] 240-56355729 Plant Control Modes Guideline

[41] 240-56355843 Pressure Measurement Systems Installation Standard

[42] 240-56355888 Temperature Measurement Systems Installation Standard

[43] 240-56364535 Architectural Design and Green Building Compliance Manual

[44] 240-56364542 Standard for Reinforced Concrete Foundations and Structures

[45] 240-56364545 Structural Design and Engineering Standard

[46] 240-56830508 Cooling Water System Care

[47] 240-60782552, Process Flow Diagram Standard;

[48] 240-61227631, Piping and Instrumentation Diagram (P&ID) Standard;

[49] 240-68604731 Design Base Standard

[50] 240-70164623 Design Guide for HVAC in Coal Fired Power Stations

[51] 240-71432150 Plant Labelling and Equipment Description Standards

[52] 240-86973501 Engineering Drawing Standard Common Requirements

[53] 240-XXX Contents of Pipeline identification Standard

[54] 240-XXX Hydraulic Analyses Design Guideline

[55] 240-56356376 On-site Commissioning for Low Pressure Systems Standard

[56] 240-XXX Standard for Low Pressure Pipelines

[57] 240-105020315 Standard for Low Pressure Valves

[58] 240-108079430 Design guideline for water systems

[59] 32-1110 Water Accounting Framework

[60] 32-1155 Standard Project Life Cycle Model

[61] EN 15614- Qualifications for welding procedure

[62] EN 267-1 Qualifications of welders

[63] SANS 2001-DP8, Construction works, Part DP8: Pipe Jacking;

[64] SANS 240-56030558 Centrifugal pumps standard

[65] SANS 347, Categorization and conformity assessment criteria for all pressure Equipment;

[66] VGB-R 171e, Guidelines for the supply of technical documentation for fossil-fired and regenerative power stations;

[67] Warren M. Rohsenow; James P. Hartnett; Young I. Cho: Handbook of Heat Transfer. HEAT EXCHANGERS, Chapter (McGraw-Hill Professional, 1998), AccessEngineering

[68] The South African Grid Code, The Network Code

2.2.3 Forms and Templates

[69] 240-49910679 Concept Design Report Template

[70] 240-49910705 Basic Design Report Template

[71] 240-49910707 Detail Design Report template

[72] 240-53113704 Maintenance Engineering Strategy Report Template

[73] 240-55864360 Mechanical Equipment List Template

[74] 240-56227927 Electrical Load List Template

[75] 240-57934588 End-of-Phase Design Review Report Template

[76] 240-60782527 Control Philosophy Report Template

[77] 240-61227624 Plant Operating Concept Report Template

[78] 240-61379718 Control & Instrumentation Instrument Schedule Template

[79] 240-61379755 Control & Instrumentation Drive & Actuator Schedule Template

[80] 240-72344339 C&I Virtual Signal List Template

[81] 240-72350241 C&I Panel Interface List Template

2.3 DEFINITIONS

Definition	Description
Anchor	A device which prevents all movements, whether linear or rotational, of a pipe or component of a piping system.
Code	A collection of compatible rules, regulations and standards prepared by a standards authority, also referred to as a code of construction or a code of practice.
Common systems	Systems to be continuously operational during any unit outage
Cooling water (Closed circuit)	Water circuit pressurised by head tank circulating water between cooling system heat exchanger and end users heat exchangers. It circulates water of higher quality than the open circuit.
Cooling water (Open circuit)	Water circuit under atmospheric pressure circulating water between cooling tower and cooling system heat exchanger. It circulates water of lower quality than closed circuit.
Demineralised water	Water that has a low concentration of solids and dissolved salts. See Eskom Standards**Error! Reference source not found.**
Design Pressure	Pressure to which equipment is designed by OEM
Dirty water	All water collected within the Power Island and surrounds which usually are contaminated with ash and oil into a dam.
Fixed Support	A device which provides vertical support without vertical movement but allows horizontal movements in both directions.
Guide	A device which allows movement of a pipe or component of a pipework system in one direction, while limiting any movement in one or two of the other directions.
Hanger	A mechanical device which supports a pipe from above.
Main cooling system	Cooling system for turbo-generating plant

Definition	Description
Pipework (ASME use Piping Elements)	The term "pipework" used herein includes pipes both straight and bent, branches, stubs, orifice carriers, flanges, gaskets and bolting, and the pressure-bearing parts of forged or cast construction for valves or fittings, including bodies, covers and bolting.
Potable water	Water suitable for human consumption complying with [35]
Process design	The process design finalises the PFD's, P&ID's and input requirements for the discipline specific detail designs.
Raw Water	Water supplied from external sources (usually the supply authority is Department of Water Affairs).
Recovery/Dirty Water	This is contaminated water collected via the water drainage systems
Restraint	Any device which exerts a force on a pipe or component of a piping system in a horizontal direction. A restraint may act in one or two directions at the same time.
Riser Clamp	A component which supports vertical pipework.
Service/Process/Filtered Water	Water used in the Power Plant which is not Raw, Potable, Demineralised or Dirty Water
Standard	The detailed requirements laid down for the supply of materials, the design of plant or equipment, the testing of materials, plant and equipment, etc. with which compliance is mandatory.
Support	Any device for exerting a vertical upward force on a pipe or part of a piping system. A tension support exerts its force from above the attachment point on the pipe, while a compression support exerts its force from beneath.
Temperature approach	Temperature difference Water out less air wet bulb temperature
Temperature range	Water temperature difference between in and out
Termination	Are those points on equipment, including tanks, pipes, dams, etc., which are either fixed points or whose movements are small and can be closely defined under varying temperature conditions, which form the actual ends of pipe systems, and between which the flexibility analysis is carried out
Unit	Turbo-generator Unit
Vibration Damper (Snubber)	A mechanical or hydraulic device which exerts a force on a pipe or piping component of a pipework system in a direction opposite to that of the movement, and of a magnitude proportionally or otherwise related to the velocity.

2.3.1 Disclosure Classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
AMCA	Air Movement and Control Associate (International)
ASME	American Society of Mechanical Engineers
BS	British Standards
DB	Dry bulb temperature
Demin	Demineralised
IEC	International Electrotechnical Commission

Abbreviation	Description
ISO	International Organisation for Standardization
LPS	Low Pressure Services
LV	Low Voltage
MAWP	Maximum allowable Working pressure
MOP	Maximum Operating Pressure
MV	Medium Voltage
NERSA	National Energy Regulator SA
NRS	National Regulator Standard (department of Energy)
NTU	Number of transfer Units
O&M	Operation and maintenance
OEM	Original Equipment Manufacturer
PLCM	Project life cycle Model
SANS	South African National Standard
SC	Study committee
SCOT	Steering committee of technology
SRD	Stakeholder Requirements Definition
SRD	Stakeholder requirement definition
WB	Wet bulb temperature

2.5 ROLES AND RESPONSIBILITIES

The Designer will be responsible to complete and document the design as indicated in this Design Guide.

The design shall be functionally approved by the professionally registered Engineer (or LDE).

The responsible EDWL shall ensure that End-of-Phase Design Reviews are scheduled as the project progresses through the project lifecycle.

The CoE manager shall authorise the design for a single discipline project and the Senior Manager shall authorise for multi-disciplinary project.

2.6 PROCESS FOR MONITORING

The process for monitoring will be governed by the Design Review Procedure.[28]

2.7 RELATED/SUPPORTING DOCUMENTS

2.7.1 Superseded

Not applicable

3. SYSTEM DESCRIPTION

3.1 AUXILIARY COOLING WATER SYSTEM DESCRIPTION

The Aux cooling system employs the evaporative cooling process and consists of cooling towers, heat exchangers and two main pumping systems, being closed and open circuit system as well as end users heat exchangers.

There are two types of closed systems, the unitised and common services. The difference is with operational requirements. The unitised systems are associated with power generation unit operation and are isolated when unit is shut off for service. The common system is used for common services and is not shut off for service and require 100% stand by equipment to facilitate maintenance.

The closed circuit pumping systems are controlled at a pressure differential to ensure a constant flow to end users equipment located at varies levels and to avoid booster pumping. Means of flow balancing are required at each tap-off from the main headers and at users. Various methods of flow balancing are available. This ranges from orifice plates to flow balancing valves. Orifice plates are least expensive but require accurate information for the whole system at the design stage. Flow balancing valves are recommended if accurate information are not available.

The unitised system is mainly used by Boiler and Turbine auxiliaries. The common system is used by the systems not directly linked to the Unit operation and required during outages. The main users for the common system are HVAC system and compressors.

The head tank level for the closed system is approx. 10 m above highest heat exchanger and must be connected in such a way to avoid it being isolated when a user or collection of users are isolated and that the supply and return headers can be commissioned while the users are not yet available The head tank performs the following functions

- Serves as an expansion tank
- Provide head pressure to the system
- Supply water on gravity principal on temporary unavailability of the cooling system (i.e. to avoid overheating of bearings) The system should be able to operate of the tank on once through principal
- Release air from the system

The open circuit is from the main heat exchangers to the sprays headers of the cooling tower cells and returns via sump to pumps. The open circuit system may be either constant or variable flow depending on the heat load variation requirements

The cooling towers remove heat from the Turbine and Boiler auxiliaries via heat exchanger to open circuit of spray water over cooling tower filament. Most of the heat (over 80%) is removed by latent heat of evaporation some heat is also removed by sensible heat removal process

The blow down system requirements depends on the water quality used and time to achieve the maximum allowed concentration of soluble salt in the system. It is controlled by water conductivity controller. The blow down from towers is connected to the station dirty water system (not to the storm water system). The large quantity of water released effects sizing of the dirty water system and is an input from aux cooling designer to this system

Make up water is supplied to the cooling tower sump. The make-up water system flow is determined taking into account water evaporating rate plus small percentage allowed for water loss due to drift and the amount of water lost due to blow down. The make-up water is usually available at a pressure from other LPS systems, alternatively, the dedicated make up pumps need to be installed.

The chemical dosing system for closed circuit can be administrated by injecting chemicals into piping system or dosing to the head tank. For aux, cooling it is more practical to dose into piping system as the tank is at high level and rarely inspected. The chemical dosing to open system is into the cooling tower sump.

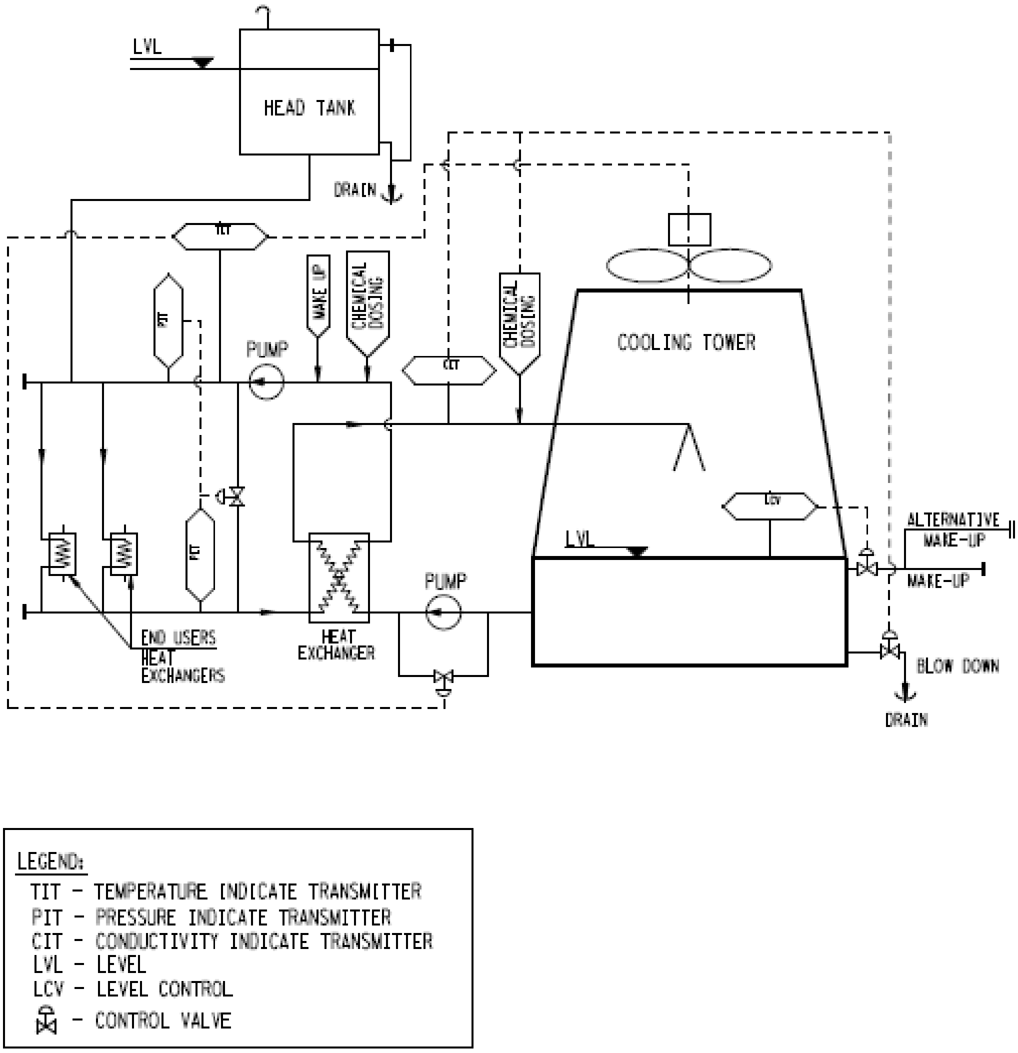

Figure 1: Typical Concept design of the cooling system

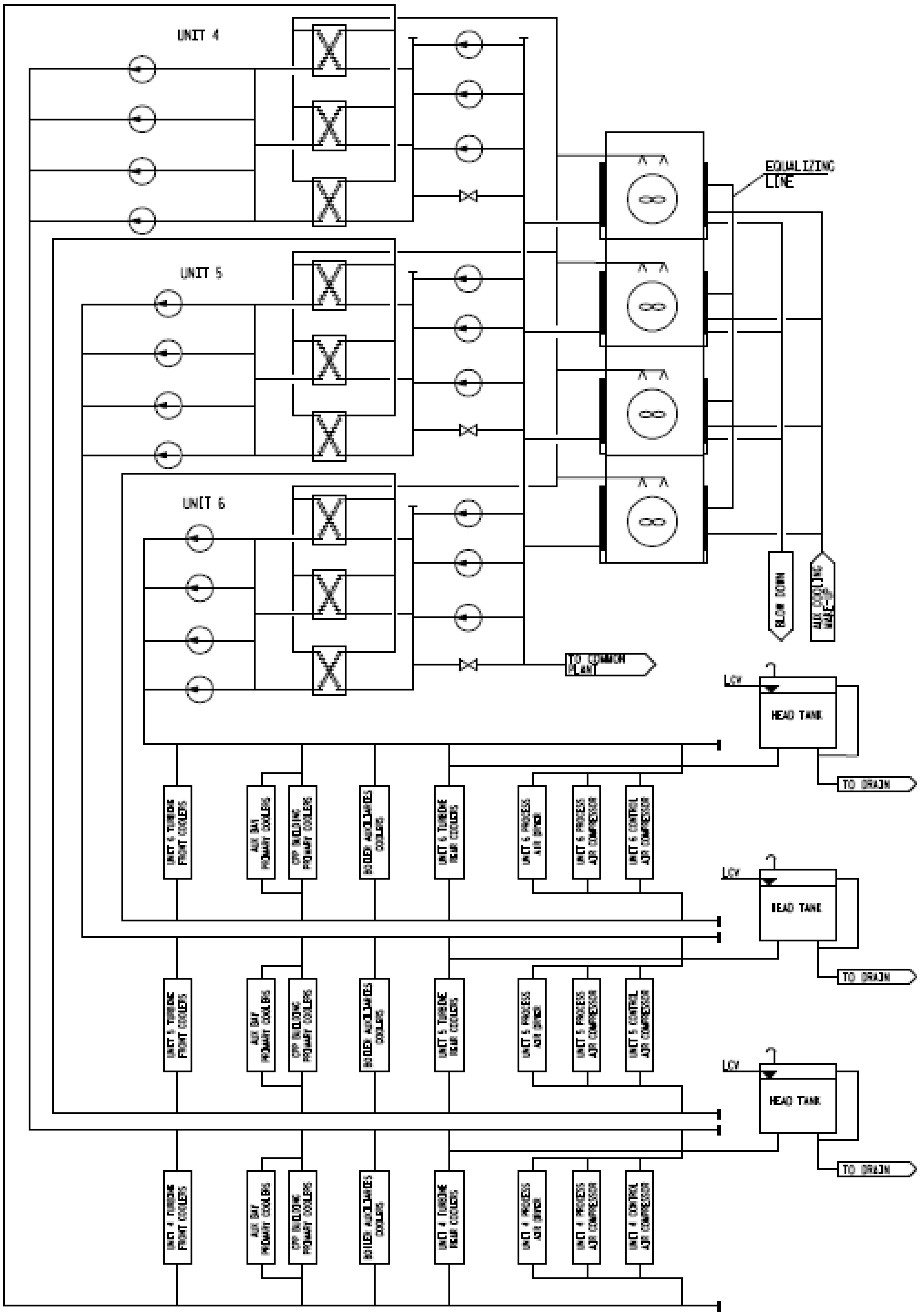

Figure 2: Flow diagram

A Flow diagram for 3 units is shown in the Figure 2. It is based on 3 power generation units of Medupi design and includes the following:

- Four cell cooling Tower
- Interconnection of cells with equalised line
- Open circuit pumping

- Connection to common system
- Heat exchangers
- Unitised closed circuit pumping
- Closed circuit distribution lines
- End users circuits
- Head tanks

3.2 AUXILIARY COOLING WATER SYSTEM USING THE MAIN COOLING WATER AS OPEN CIRCUIT (IE BOILER AUX. COOLING)

The main cooling water system, utilised mainly for cooling of the condensate of steam, is used in some older Power Stations to cool the auxiliaries. This system pipelines correspond to the pipelines used on the main system. The control of this system is generally at the end users heat exchanger

The open circuit is supplied with water of the main cooling system. . The pressure of the main system is usually sufficient and the additional pumps are not required however the pressure control valves or orifices for controlling of the flow may be installed for the auxiliary cooling lines. The strainers, strainers, strainers automatic cleaning will also be needed prior to heat exchanger. Temperature monitoring and controlling by providing bypasses to protect against winter overcooling might also be needed.

The closed water circuit usually employ different type of water to open circuit. The comments of closed circuit auxiliary cooling as described in item 3.1 generally apply.

3.3 STAND-ALONE EVAPORATIVE COOLING WATER SYSTEM

The stand-alone evaporative cooling system consists of commercially available Cooling Towers, pumps, water distribution, chemical dosing for water treatment and controls.

Cooling Towers are direct cooling (open type) or indirect cooling (closed type).

In open type tower the evaporative cooling is achieved by splashing water directly to the tower fill and assisting evaporation by forced or induced type fan.

In closed type tower the coolant is in the heat exchanger which is cooled by an additional/open circuit splashing water over the heat exchanger, assisted by forced or induced air fan

The Cooling Tower enclosure and fill material vary and is dependent on corrosively of cooled and cooling media. It usually is constructed with galvanised steel, stainless steel or fiberglass

The system is often used on the smaller cooling systems (i.e. cooling of heat rejection from air conditioning chillers, sample analysis cooling, compressors etc.). Those systems usually have an independent water treatment dosing system and control system. The HVAC related specification of this type of equipment is included in Eskom spec 240-102547991 General Technical Specification for HVAC system

For the purpose of industrial cooling closed type of Towers are preferred. The materials used for Tower construction depend on the type of cooled and cooling media.

4. DESIGN PROCESSES

4.1 PROJECT LIFECYCLE MODEL

All projects are required to conform to an approved governance framework which is used to govern the work of the project, management approval and project investment process.[60]

The Project Life Cycle Model (PLCM) is a hierarchically structured process grouping, logically relating elements of project work together in phases. This process facilitates the planned implementation of project work to create specific outputs in the correct sequence, without incurring excessive cost or risk. It facilitates management decision making to maximise the allocation of limited resources.

It is important to note that the PLCM phases are based on the investment decisions that need to be made. Reference [26] provides more detail regarding the design phases.

4.2 DESIGN REVIEW PROCEDURE

The design review procedure [28] defines certain end of phase design reviews but also allows for design freeze reviews which need to be defined for the specific situation. Section 4.3 below indicates the major design milestones recommended for the auxiliary and ancillary cooling water systems.

The design review procedure provides for the governance that prescribes a series of evaluations to determine the adequacy, correctness and adherence of designs in achieving objectives at each pre-defined phase of the design review procedure. The design review procedure is crucial for obtaining approval and acceptance for designs during the execution of the different phases in the Project Life Cycle (PLC), thereby authorizing the release to the following phase of the design process.

Design reviews provide the necessary assurance that all previously set requirements at the end of each phase has been satisfactorily met. This ensures that a credible basis is set for the next phase in the PLC. Properly conducted design reviews will assist in avoiding re-work and will reduce the risk of adversely affecting project deliverables in terms of cost, quality, time and scope.

In order to conduct design reviews, it is essential to define end of phase baselines. These baselines will describe the requirements that need to be met for each phase/stage in the PLC in terms of designs, standards and deliverables.

4.3 MAJOR DESIGN MILESTONES

End-of-Phase Design Reviews Error! Reference source not found. Are performed to establish design Baselines and to ensure the correctness, completeness, conformance and integrity of a design. End-of-Phase reviews are performed at key milestones during a project's life cycle, normally at the end of a defined phase in the project.

The following is the major design milestones recommended for the auxiliary and ancillary cooling water systems.

- *Stakeholder Requirements review
- Concept Design Review
- Basic Design Review
- Process design freeze Review
- Arrangement design Freeze Review
- Mechanical detail design Freeze Review
- *Civil design Freeze Review
- *Electrical detail design Freeze review
- *C&I detail design Freeze Review
- Integrated design Review
- *Pre-commissioning review
- *Acceptance Testing Review

- *Handover review
- *Pre-Enquiry design review
- *Contract Award Review

The detail regarding the milestones marked with an "*" are outside the scope of this guideline and is included for clarity only.

4.4 CONCEPT DESIGN

The SRD will provide the information to proceed with a concept design. The SRD presents a comprehensive set of stakeholder requirements for system development and covers all functions, performance and constraints.

The purpose of the concept design phase is to demonstrate and qualify that there is a feasible solution(s) to satisfy stakeholder requirements and to define the preferred solution, in sufficient detail, to enable its performance, engineering timescales and life cycle cost to be predicted in quantitative terms.

Elicited stakeholder requirements are transformed into technical requirements of the system as a whole, and into technical requirements of those major subsystems and components that are significant technical design and cost drivers. Furthermore, a preferred system configuration is selected from among the alternative concept designs.

During this phase, the identification and management of technical risks commence.

Conceptual Engineering are carried out by a wide variety of parties who will generally involve the Engineering Disciplines, Systems Engineering, Maintenance, Operations, Environmentalists, etc. Care should be taken only to do as much engineering in this phase as is necessary to identify and shortlist the alternatives and to finalise system requirements.

Table 1: Concept design activities

Activity	Output Document	Reference paragraph
Obtain User Process Requirements	Concept Design Report (8.1)	5.5; 5.6
Estimate total Heat Load	Concept Design Report (8.1)	
Determine alternatives	Concept Design Report (8.1)	5.1
Evaluate alternatives and confirm best option	Concept Design Report (8.1)	5.1
Create Overview diagram	Overview diagram (8.5)	5.22
Determine Conceptual plant layout	Conceptual plant layout drawings (8.13)	5.20; 5.21; 5.19
Document Concept design	Concept Design Report (8.1)	
Perform Concept design review	End of phase design review report	

4.5 BASIC DESIGN

The purpose of the basic design phase is to establish a complete technical baseline for the system design, including all subsystems, in sufficient detail for detailed design. The intent, in the Eskom context, is to develop specifications against which the detailed design and further engineering activities can be contracted out. Furthermore, any major technical uncertainties or risks are resolved through analysis or technology selection. During this phase ambiguities in initial system requirements are eliminated and the design is further optimised through trade-off studies.

Basic Engineering is simply enough engineering to define and fix the scope of the Project, to finalise the project strategy and to produce a Semi Definitive Estimate. The actual extent of Basic Engineering required will vary from Project to Project and it is not possible set hard and fast rules as to what is an appropriate level of engineering. It becomes a matter of judgment to set the correct balance between doing excessive engineering work which may be wasted if the project is not approved and doing enough engineering to correctly fix the scope and estimates.

Table 2: Basic design activities

Activity	Output Document	Reference paragraph
Confirm User Process Requirements	Basic Design Report (8.2)	5.5; 5.6
Develop/Update PFD for the existing systems.	Process Flow Diagram (8.6)	
Develop/Update P&ID for the existing systems.	P&ID (8.7)	
Determine Water properties	Basic Design Report (8.2)	5.2
Determine environmental conditions	Basic Design Report (8.2)	5.3
Determine system configuration	Basic Design Report (8.2)	
Develop Plant Operating Concept	Basic Design Report (8.2)	5.18
Determine operating scenarios to be evaluated in the design	Basic Design Report (8.2)	5.4
Perform basic process calculations	Basic Design Report (8.2)	5.5
Perform basic hydraulic calculations	Basic Design Report (8.2)	5.6
Update Overview diagram	Overview diagram (8.5)	5.22
Determine Basic Plant Layout	Basic Plant layout drawings (8.14) 3D Model (8.12)	5.15; 5.16; 5.20; 5.21
Establish Pipe and Cable routes	Pipe and cable routing Drawings (8.16)	5.20
Determine Design Code	Basic Design Report (8.2)	5.7
Determine plant performance specifications	Basic Design Report (8.2)	
Determine piping system to be used	Basic Design Report (8.2)	5.10; 5.17
Determine equipment requirements	Basic Design Report (8.2)	5.17; 6; Appendix B
Establish long lead items	Equipment lists (8.9)	6

Activity	Output Document	Reference paragraph
Estimate power requirements and IO count	Basic Design Report (8.2)	
Perform FMECA study	FMECA Report (8.21)	
Update documents base on the outcome of the FMECA study		
Determine RAM requirements	Basic Design Report (8.2)	5.19
Determine acceptance test requirements	Basic Design Report (8.2)	7
Document Basic Design	Basic Design Report (8.2)	
Perform Basic Design review	End of phase design review report	

4.6 PROCESS DESIGN

The process design finalises the PFD's, P&ID's and input requirements for the discipline specific detail designs.

Some of or all the activities forming part of the Process design can be incorporated in the Basic design or detail design depending on the situation.

Table 3: Process design activities

Activity	Output Document	Reference paragraph
Confirm Water properties and environmental conditions	Process design report (8.3)	5.3
Confirm operating scenarios to be evaluated in the design	Process design report (8.3)	5.4
Perform detail process calculations	Process design report (8.3)	5.5
Develop PFD and actual mass and energy balance for system.	Process Flow Diagram (8.6)	5.22
Perform detail hydraulic analysis	Process design report (8.3)	5.6
Update PFD and actual mass and energy balance for system.	Process Flow Diagram (8.6)	
Create Control Philosophy	Control Philosophy (8.8)	5.18
Create Plant layout drawings	Plant layout drawings (8.15); 3D Model (8.12)	5.15; 5.16; 5.20; 5.21
Develop/Update P&ID indicating all equipment	P&ID (8.7)	
Create/update Equipment List/Schedules	Equipment lists/schedules (8.9)	5.17; 5.18; 6
Perform Hazop study	Hazop Study Report (8.22)	
Perform RAM analysis	RAM analysis report (8.23)	5.19

Activity	Output Document	Reference paragraph
Update documents based on the outcome of the HAZOP study and RAM analysis	End of phase design review report	
Complete Process Design Report	Process design report (8.3)	
Perform Process Design review		

4.7 ARRANGEMENT DESIGN

The arrangement design comprises of the activities for performing an integrated plant layout design that conforms to specific criteria and will result in an optimal constructible, operable and maintainable layout design.

A site and civil facilities layout design is performed to identify and resolve clashes and ensure that adequate provisions are made for pumps, piping and support structures for system maintenance, operational support, human factors, regulatory requirements and emergency access and prevention or mitigation of identified hazards (fire hazard, environmental, process and other induced hazards).

The site layout includes all earthworks, terracing, storm water, dams, sewerage, structures, electrical overhead and trenched reticulation, earth-mat, piping routes, roads, rail, conveyors, loading, unloading and storage facilities, buildings, fencing, raw material and waste holding areas and line profile as a topographical terrain model.

The steps/actions listed in this section are only the auxiliary and ancillary cooling water systems specific requirements and is not a complete list.

Table 4: Arrangement design activities

Activity	Output Document	Reference paragraph
Finalise plant layout	Plan layout drawings (8.15)	5.15; 5.16; 5.20; 5.21
Allocate space and servitudes for equipment.	Servitude defining drawings (8.17) 3D model (8.12)	5.15; 5.16; 5.20; 5.21
Determine General Arrangement	Arrangement Drawings (8.18) 3D model (8.12)	5.15; 5.16; 5.20; 5.21

4.8 MECHANICAL DETAIL DESIGN

The purpose of the detailed design phase is to complete the designs to the lowest level required, such that they may be released for manufacture or component procurement after formal design and integration reviews. The detailed design phase may be contracted out and the primary role of Eskom's engineering function is to ensure the next level integration, to verify compliance with the requirements and to review the safety of the detailed designs. Finalise the design by consolidating the final design input and output documents and compile the design report.

Table 5: Mechanical detail design activities

Activity	Output Document	Reference paragraph
Specify Equipment	Equipment lists/schedules (8.9) Equipment specifications (8.10)	5.17; 6
Determine equipment arrangement	Arrangement drawings (8.18) 3D Model (8.12)	5.19; 5.20; 5.21; 5.22
Design of tanks and vessels	Detail drawings (8.20); Mechanical detail design report (8.4)	5.11; 5.14; 5.17
Design piping	Piping isometric drawings (8.19)	5.10
Perform pipe stress analysis	Mechanical detail design report (8.4)	5.10.4
Update piping design based on pipe stress analysis	Piping isometric drawings (8.19)	
Design equipment and pipe supports	Detail drawings (8.20); Mechanical detail design report (8.4)	5.16; 5.17
Obtain OEM equipment data sheets	OEM Equipment Data sheets (8.11)	
Complete Mechanical Detail Design Report	Mechanical detail design report (8.4)	
Perform Mechanical Detail Design review	End of phase design review report	

4.9 INTEGRATED DESIGN

The integrated design establishes the functional coherence of the system and consistency is verified across subsystem and component designs. This is achieved by taking into consideration actual subsystem design data to perform the following integration activities:

Table 6: Integrated design activities

Activity	Output Document	Reference paragraph
Confirm process integration		5.5; 5.6; 5.7; 5.9; 5.10; 5.11; 5.12; 5.13; 5.14; 5.17; 5.18; 5.22
Confirm arrangement integration		5.20; 5.21; 5.22
Perform integrated HAZOP study	HAZOP study report (8.22)	
Perform integrated design review	End of phase integrated	

Activity	Output Document	Reference paragraph
	design review report	

5. AUXILIARY AND ANCILLARY COOLING WATER SYSTEMS DESIGN CONSIDERATIONS

5.1 ALTERNATIVE CONCEPTS

The SRD forms the basis for the system concepts. The following should be considered when determining alternative concepts:

- Frequency of system use i.e. can rental/hired equipment be used.
- Electrical power supply location.
- C&I hardware location
- Maintenance history/ Lessons learnt.
- Operational history in Eskom.
- Other concepts which do not include the construction of a piping system.
- Costing of alternatives for major equipment
- The required design life taking in account the remaining life of the power station

Leave system as is alternative that should also be considered.

5.2 WATER PROPERTIES

The water properties for Cooling water systems are governed by the “Chemistry for Auxiliary and Ancillary Cooling water systems Manual” [36][37] The systems are divided in the following categories:

- closed systems with demineralised water make up,
- closed systems with potable water make-up,
- open evaporative systems with potable and raw water make-up,
- open evaporative systems with demineralised water make-up.

Proper water chemistry should be applied to prevent fouling and calcification in the heat exchangers.

5.2.1 Open circuit

It is recommended that in new systems open circuit uses potable water or filtered raw water and as a backup untreated raw water. The choice of water type involves cleanliness of the raw water, maintenance cost of towers and cost of water production

Water quality in open circuit can be also influenced by external sources (i.e. fly ash, excessive wind, swarm of insects etc.). The design and maintenance regime has to take this condition into consideration

Water treatment dosing as well as blow down cycle shall be based on control of the supply water conductivity.

5.2.2 Closed circuit

The closed circuit of the auxiliary cooling utilises demineralised water. The water is inhibited with suitable organic chemicals to protect steel against corrosion. The usage of copper in heat exchangers should be avoided or other inhibitor for protecting copper has to be also administered.

5.3 ENVIRONMENTAL CONDITIONS

The design condition is based on the Weather Bureau data. The maximum DB temperature and maximum WB temperature for summer and minimum DB temperature for winter is taken as design condition.

The Weather Bureau does not list temperature and associated relative humidity (RH) as one set of data. The designer has to interpret data, study hourly temperatures and hourly humidity to establish the outdoor condition.

The criteria of weather condition as specified for the main cooling system shall be adopted.

5.4 SCENARIOS TO BE EVALUATED IN THE DESIGN

The system must be designed to operate as intended for all operating scenarios. A set of scenarios need to be determine which represent all possible system operating scenarios. This set of scenarios is used when analysing the system. It is important not to only analyse the maximum flowrate scenario. The following needs to be considered:

- Different weather conditions
- Multi-unit trip (Compliance to "The South African Grid Code" [68])
- Return after blackout (Compliance to "The South African Grid Code" [68])
- Simultaneous use on more than one unit
- Partial load conditions i.e. units isolated or out of operation
- Systems required during unit outage.
- Commissioning sequence (including all users isolated, no heat load from users)
- Pumps running at no flow conditions (resulting in high pressure)
- Events causing pressure pulses (e.g. Closure of flow in a pipeline)
- and Seismic events

5.5 PROCESS CALCULATIONS

The following steps are recommended auxiliary and ancillary cooling water systems process design:

- Determine design heat load (User heat load times safety factor for heat transfer in the piping, leaks and unforeseen conditions);
- Determine maximum closed circuit supply temperature;
- Determine temperature differential across the closed circuit supply and return headers;
- Calculate total flow requirement for closed circuit (including flow through pressure control valve);

$$Q = \frac{q}{c} * \rho * dT$$

Where

Q-flow (m^3/s)

q- heat dissipation in kW (kJ/s)

c- specific heat (kJ/kg K)

ρ-density (kg/m^3)

dT (t_1-t_2): Temperature differential water returns less water supply to the system (K)

- Determine total flow requirement for open circuit. It is recommended that the heat exchanger be balanced (open circuit flow through the heat exchanger equals the closed circuit flow through the heat exchanger). Not applicable where Main Cooling Water system is used as the open circuit.
- Determine the open circuit heat exchanger inlet and outlet temperatures (using the effectiveness-NTU method). Not applicable where Main Cooling Water system is used as the open circuit.
- Determine cooling tower design heat load. Not applicable where Main Cooling Water system is used as the open circuit.
- Determine the head tank capacity. The capacity must include allowances for thermal expansion and for emergency supply during power failures.
- Determine level of head tank.
- Determine closed circuit make-up requirements. The closed circuit make-up requirements are based on the time needed to fill the system.
- Determine Blow down requirements. Blowdown of the open circuit is required due to concentration of salts.
- Determine open circuit make-up requirements. Make up for open circuit is significant and caused by evaporative loss of water, drift on the tower as well as blow down. Not applicable where Main Cooling Water system is used as the open circuit.
- Determine sump capacity. The capacity is calculated as a function of timing between make up and blow down cycle. Not applicable where Main Cooling Water system is used as the open circuit.

Table 7 Typical design parameters for auxiliary cooling water systems

Item	Description	Value	Comment
1	Differential temperature across Closed circuit supply and return headers.	6°C	
2	Maximum closed circuit supply temperature	32°C	Emergency maximum supply water temp 38°C
3	Minimum flow through pressure control valve	10% of the total flow	The flow will depend on the specific valve being used. It is important that the control valve stays within its control range.
4	Safety factor for heat transfer in the piping, leaks and unforeseen conditions	1.05	A larger factor needs to be use in the early design stages if the heat loads from the users are uncertain.
5	Heat exchanger effectiveness	0.6	
6	Wet bulb design temperature	20°C	The wet bulb temperature must be confirmed using data from the Weather Bureau.
7	Differential pressure	200 kPa	Pressure is controlled between main supply and return water lines by operation of bypass line control valve

Item	Description	Value	Comment
8	Cooling tower drift losses	2%	
9	Cooling Tower evaporative losses at 20°C WB temperature	2257kJ/kg	
10	Cycle of concentration	6	This value is dependent on the quality of the make-up water.
11	Emergency supply time from Head tank for selected user's heat exchangers	2.5 hours	Based on Medupi unitised system design

5.6 HYDRAULIC CALCULATIONS

The flow in a piping system can be described by the Bernoulli equation. System resistance curves can be developed for the friction loss through a piping system. A system characteristic will be developed for the system by using the principle that the friction pressure drop varies directly with the square of the flow.

The most common engineering design flow loss calculation selects a pipe size for the desired total flow rate and available or allowable pressure drop. Noise, erosion and operating costs all limit the maximum and minimum velocities in piping systems. Pipe sizes are chosen to minimize initial cost while avoiding the undesirable effects of high velocities. Corrosion and fouling allowance cganging pipe diameter

Hydraulic calculations will include the following:

- Head loss through piping system. The friction factor is a function of pipe roughness, inside diameter and the Reynolds number. Allowance should be for aging and erosion.
- Pressure required for equipment to be operated i.e. water spray nozzles and elevation between water source and delivery point.
- Head loss through components and equipment. Valves and fittings can cause greater head losses greater than those caused by the pipe line alone. The head losses are expressed as:

$$h_L = k\frac{V^2}{2 * g}$$

Where

h_L = Head loss (m)

V = Fluid velocity (m/s)

g = gravimetric acceleration (9.82 m/s^2)

k = Head loss coefficient

Table 8: Recommended Maximum Pipe velocities

Item	Velocity	Comment
Pump suction piping	1.5 m/s	Suction line to be close to pump such that pump NSPH is higher than the suction losses
Pump discharge piping	2.5 m/s	
Gravity feed	2.5 m/s	This value is applicable when it is practical to change the available Head.

The amount and accuracy of the input data increases as the design progresses through the various design stages. It is important that the input data are confirmed during each design stage.

The table below contains the typical accuracy of process input data at each of the major design milestones.

Table 9: Accuracy of Process input data

Item	Concept design	Basic design	Process design	Detail design
Flow rate (maximum and minimum)	± 12 %	± 5%	± 2.5%	± 1%
Pressure (system head)	± 25 %	± 10%	± 5%	± 1%
Pipe lengths	± 25 %	± 10%	± 5%	± 1%
Secondary head losses (fittings etc.)	± 25 %	± 10%	± 5%	± 1%
Water levels of tanks and reservoirs	± 12 %	± 5%	± 2.5%	± 1%
Temperature (Maximum and minimum)	± 10%	± 10%	± 10%	± 10%

Allowances need to be made for the above inaccuracies when determining the following:

- Size of plant areas;
- Size of pipe servitudes.
- Forces on civil structures a pipe supports.
- Power requirements;
- Measurement range of instruments

5.7 DESIGN CODES

Codes sets forth engineering requirements deemed necessary for safe design and construction of pressure piping. While safety is the basic consideration, this factor alone will not necessarily govern the final specifications for any piping system. The designer is cautioned that the Code is not a design handbook; it does not do away with the need for the designer or for sound engineering judgment.

Pressurised Systems are governed by the Pressure Equipment Regulations [5]. The Pressure Equipment Regulations require all pressure equipment to be categorised and submitted to the applicable conformance assessments of SANS 347. The piping in auxiliary and ancillary cooling water systems is excluded from these regulations because it is used for the supply, distribution and discharge of water below its boiling point at atmospheric pressure. It is however recommended that all piping in cooling water system conform to SANS 347.

The following Design Codes listed in SANS 347, as health and safety standards as approved by the Department of Labour, are suitable for use with cooling water systems:

- EN 13480 (All parts) Piping
- ASME B31.1 Code for pressure piping – Power piping
- ASME B31.3 Code for pressure piping – Process piping
- PD 5500 Specification for unfired fusion welded pressure vessels
- ASME Section VIII Rules for construction of pressure vessels (divisions 1, 2 and 3)

In general codes shall not be mixed and the choice depends on the application. One of the important criteria to be used in selecting a design code is the design code used for other systems within the specific power plant.

It is recommended that all cooling water systems comply with a design code even if it is not required by SANS 347.

5.8 OPEN COOLING TOWER DESIGN

The cooling tower system shall include but not be limited to the following design issues

- Cooling tower internals (splash fill);
- Cooling tower water boxes and removable outlet screens;
- Fans and motors variable speed recommended for cooling towers for water temperature control;
- Instrumentation
- Make-up and blow-down systems connection and control;
- Equalizing line between cells of the Tower
- Earthling and lightning protection of the structure.

The water outlet connections shall be designed to avoid vortex forming.

The cooling tower design shall include for requirements that the open circuit pump suction header and pump volute shall always be at a positive water head. This creates challenge if the Cooling Tower sump and pump is on the same level. The pipe connection to the suction shall be short with a minimum amount of fittings to avoid excessive suction head loss.

All components of cooling towers shall be constructed from corrosion resistant materials, bearing in mind their exposure to weather, polluted air and various water treatment systems and chemicals.

The each cell capacity is controlled by the directly driven draw through Variable Speed fans.

The cells are interconnected via normally opened valved pipes connecting the tower cells sumps. The interconnection should allow isolating of any cell for maintenance without interruption of operation of the other cells.

The selection of number of tower cell depends on pattern of maintenance (i.e. always one Unit is in scheduled maintenance), civil engineering constrains, the layout constrains, the market preferences (i.e. at Medupi the winning supplier was better positioned to equip smaller tower so 4 tower cells per 3 Units were proposed not 3 towers per 3 units as originally designed) and cost .From Medupi and Kusile experience it can be concluded that 4 tower cell arrangement is a recommended solution for future designs.

5.9 PUMPING SYSTEM DESIGN

5.9.1 Open circuit pumps

The open circuit pumps are normally centrifugal pumps. . The Eskom standard 240-56030558 shall apply.

Particular attention must be given to the suction pressure of the water as it enters a pump. If the absolute pressure on the liquid at the suction nozzle approaches the vapour pressure of the liquid, cavitation occurs and form vapour pockets in the impellor passages. The collapse of vapour pockets can cause progressive damage of the impellor.

The amount of pressure in excess of the vapour pressure required to prevent the formation of vapour pockets is the net positive suction head required (NPSHR). This is a characteristic of a given pump. The NPSH available (NPSHA) will be calculated and if this is less than NPSHR cavitation, noise, inadequate pumping and mechanical problems occur.

Air accumulation in the suction line of a pump will decrease the NPSHA. Local high point must therefore be avoided in pump suction lines. Tank or sump outlets must be designed to prevent vortex forming.

The pumps must be positioned as close to the source as possible.

Pump suction strainers are required to protect the pumps and prevent blockage of nozzles. Special attention should be given to the positioning of strainers which can cause high pressure drop. The design should allow for automatically bypass and washing of the strainers

5.9.2 Closed circuit pumping

The closed circuit pumps operate under static pressure of the head tank. The NPSH available is normally not a problem but needs to be confirmed.

The closed circuit utilise multiple parallel connected pumps. The pumps are usually arranged on unit basis plus common services pumps

At least one standby pump per system must be provided

The Cooling Systems usually use centrifugal pumps. The Eskom standard 240-56030558 shall apply

5.10 PIPING SYSTEM DESIGN

A piping system can be regarded as one single system provided it conveys substances having the same properties and it is as a whole designed for the same allowable pressure. The pipe material, joining method and supporting method should be consistent across a single piping system.

The following factors need to be considered:

- Suitability of the pipe material for the fluid being transported
- Minimum and maximum temperature of the fluid being transported
- Maximum working pressure
- Pipe size or size range
- Availability of fittings
- Physical environment of above and below ground pipes.
- Stability of soil for buried piping and supports
- Pipe support elements
- Expected life of the pipes
- Security of supply to the end user
- Purchase, installation and maintenance cost
- Code requirements

The codes provide minimal assistance with any of these decisions as the codes are not design manuals.

5.10.1 Pipe material

Some pipe materials are more suitable for a particular fluid than others. The Designer must determine which material is the most suitable.

Ideally the base material of the pipe must be resistant to the fluid because coatings do deteriorate with time. Also, the quality of the coating is essential which often is problematic. For economic reasons an inferior base material with a protective coating is sometimes specified.

Carbon steel is recommended for cooling water systems. Refer to section 5.17 for recommendations regarding corrosion protection.

5.10.2 Joining method

In general for carbon steel piping threaded connections are used up to 50 NB and flanged or welded connections for piping above 50 NB.

5.10.3 Pipe supports

Pipe supports can be an anchor or a guide. An anchor prevents all relative pipe rotation and displacement at the point of application while a guide permits pipe movement in a pre-determined direction while preventing movement in other directions. Pipes can either hang or be supported from below. Pipe supports used for cooling water systems pipework includes the following:

- U straps
- U-bolts,
- rod hangers,
- anchors,
- pipework guides to accommodate movement between fixed points will be needed

Tables for standard support distances are available in applicable Codes and Standards.

5.10.4 Pipe stress

High stress in a piping system will result in failure of the piping. The design codes prescribe rules on how the piping system needs to be designed to prevent these failures.

The following forces need to be considered:

- Internal pressure;
- Weight of the pipe and content;
- Momentum changes of the fluid;
- Thermal expansion;
- Poison effect for non-metallic piping;
- Reaction force by supports and other equipment;
- Seismic effects.

Detailed stress calculations are seldom required because standard pipes have ample thickness to sustain the pressure and longitudinal stress due to weight and assuming that the pipe is properly supported in low pressure services.

The cooling water systems pipework shall be designed on the basis of the following:

- The calculated primary stresses due to internal pressure, mass, support reaction loading, cold pull, etc., where applicable are within those allowed under the agreed code of construction for the specified life;

- The calculated secondary stresses due to restrained thermal expansion shall be within the allowable stress range as defined by the agreed code of construction for the specified life;
- The analysis methodology for any dynamic event shall be in compliance with the agreed code of construction
- The stress intensifications due to changes of shape, geometry, material and/or positions of weldments are minimized.
- Stress at equipment

5.11 AIR ACCUMULATION

Air in water systems is usually undesirable because it causes flow noise, allows oxygen to react with piping materials and sometimes prevents flow in parts of the system. Free air can be located in a pipeline as a result of incomplete filling, inadequate venting, leaks under vacuum, air entrained from pump intake vortexing, and other sources.

The solubility of air in water, increases with pressure and decreases with temperature. Henry's law can be used to determine amount of dissolved gasses that can be released form the water. It states that the amount of dissolved gas is proportional to its partial pressure in the gas phase. The proportionality factor is called the Henry's law constant.

Air will accumulate at high points and needs to be removed as the air can cause lower performance of the system. Most water systems use air release valves to remove air. Provide air release valves at high points.

Both the beneficial and detrimental effects of free (entrained or entrapped) air in water pipelines will be discussed with reference to water hammer and surging in the following paragraphs.

5.12 VACUUM IN PIPELINE

A pressure in the pipe below the surrounding atmospheric pressure can cause the pipe to implode at the weakest point. The following are some of the causes of a vacuum in a pipeline:

- Closure of a valve in piping can cause a negative pressure surge.
- High points in the pipeline.

Vacuum breakers should be provided in the pipeline at selected points based on calculations done by the designer or equipment suppliers.

The hydraulic gradient of piping should be calculated for pipes that do not follow a smooth even gradient. The Significance of the Hydraulic Gradient is that when a pipe is laid, attempts are made to keep the pipe at or below the hydraulic gradient. Above this height/gradient sub-atmospheric pressures and vapour cavity can form.

Air vacuum and air release valves is a method for preventing sub-atmospheric pressures and vapour cavity formation. Proper location and size of air-vacuum valves can prevent water-column separation and reduce water hammer effects.

5.13 WATER HAMMER AND SURGING

Water hammer can be defined as a pressure wave that occurs in a fluid line when flow is forced to stop or change direction suddenly (causes a momentum change). In pipelines, sudden changes in the flow (velocity) can occur as a result of pump and valve operation, vapour pocket collapse, or even the impact of water following the rapid expulsion of air out of a vent, air release or a partially open valve.

Successive reflections of the pressure wave result in alternating pressure increases and decreases, which are gradually attenuated by fluid friction and imperfect elasticity of the pipe. Periods of reduced pressure occur while the reflected pressure wave is traveling in the pipe. Degassing of the liquid may occur, as may vaporization if the pressure drops below the vapour pressure of the liquid. Vaporization may lead to what is often called liquid column separation; subsequent collapse of the vapour pocket can result in pipe rupture.

Surging.is an unsteady phenomenon governed solely by inertia. Often termed mass oscillation or referred to as either rigid column or inelastic effect.

The fundamentals of water hammer, an elastic process, and surging, an incompressible phenomenon, are both developed on the basis of the basic conservational relationships of physics or fluid mechanics. The acoustic velocity stems from mass balance (continuity), while the fundamental water hammer equation of Joukowsky originates from the application of linear momentum.

Joukowsky equation is the fundamental relationship relating water hammer pressure change with velocity change and acoustic velocity. Strictly speaking, this equation is only valid for sudden flow changes.

The following design measures can be implemented to prevent and limit the effect of water hammer

- Prevent valves from closing to fast as the flow in the pipe will be slowly decelerated.
- Prevent sudden stopping of the pump and install non-return valves.
- Consider lowering the fluid velocities.
- Shorter lengths of straight pipe, i.e. add elbows, expansion loops. Water hammer is related to the speed of sound in the fluid, and elbows reduce the influences of pressure waves.
- Install surge tanks or standpipes
- The admittance of air into a piping system. This can be effective, but the design of air vacuum-valve location and size is critical. If air may be permitted into pipelines careful analysis would have to be done to ensure effective results.
- Install a hydro-pneumatic device similar in principle to a shock absorber called a 'Water Hammer Arrestor', to absorb the pressure wave.

A combination of devices may prove to be the most desirable and most economical.

5.14 SEDIMENTATION

Sedimentation may be applicable to open circuit of cooling water systems.

Sedimentation will be prevalent in pipes and equipment when the system is not in operation for a period of time. Low velocities can also cause sedimentation.

Sedimentation can cause that:

- Valves cannot close properly resulting in leaks when used for isolation,
- Pipes get blocked.

The following can prevent sedimentation and/or reduces the effect of sedimentation on the effectiveness of the system:

- Remove the particles from the system but using equipment such as strainer and clarifiers.
- Add scour valves to the system.
- Ensure that the velocity in the pipe is above the settling velocity.
- Flush the piping before the system is shut down.

5.15 HOUSING OF THE EQUIPMENT

Equipment (mechanical, electrical and C&I) can be housed in an enclosed building, under a shelter or in an open environment on appropriate concrete bases.

See reference [43] which describes the architectural design of the housing

HVAC is to be considered for the building, if natural ventilation is not able to remove the heat load of equipment [50].

The main auxiliary cooling water systems are normally in the open.

5.16 STRUCTURAL STEELWORK AND FOUNDATIONS

Structural steel may be required where pipes are above ground, crosses over roads or multiple pipes are supported. Foundations are required to support all the structural steel, equipment and cooling tower structure.

All these elements will be designed according to the applicable Civil Engineering Codes [45]

5.17 CORROSION PROTECTION

The type of corrosion protection for modifications to existing installations should be compatible with the specifications already in use.

Detail corrosion protection specifications need to be developed in conjunction with the corrosion protection section within RT&D. The external coating must be selected to withstand water spray from the cooling towers.

5.18 SYSTEM CONTROL

Plant Control Modes Guideline document [40] is to serve as a guideline for selecting plant control modes. The operating modes need to be considered and the operating philosophy is based on a level of automation where the plant is in auto mode for all normal operations. The Process designer needs to, at an early stage in the design process, clarify all C&I related design aspects with the C&I Designer.

Control & Instrumentation Schedule Templates (refer to list in sections 0) provide for specific information that needs to be supplied by the process designer to the C&I Designer

5.18.1 Control of the auxiliary and ancillary cooling water systems

Below are listed details of the Auxiliary System control points. The main issues are indicated at figure 1 (System description) and emphasised below

- Pump change-over control under any pump motor trip condition.
- Closed circuit pressure control.
- **Cooling water temperature control.**
- Closed circuit make-up control (via head tank level).
- **Open circuit make-up control.**
- **Open circuit blow-down control (via conductivity).**
- Heat exchanger backwash control

5.18.2 Typical Measurements for auxiliary and ancillary cooling water systems

The following measurements are common on cooling water systems

Table 10: Typical Measurements for cooling water systems

Measurement	Indication	Reason
Cooling tower water level	Control room	Used to control the open circuit make-up.
Strainer/filter differential pressure	Local and Control Room	Provide information regarding the cleanliness of the strainer/filter
Pump suction pressure	Local and Control room	Provide indication for cavitation
Pump discharge pressure	Local and Control room	Provide indication of the pump performance and if the discharge line is restricted.
Heat exchanger common upstream pressure	Local and Control room	Used to determine fouling of heat exchangers
Heat exchanger common downstream pressure	Local and Control room	Used to determine fouling of heat exchangers
Supply Header pressure	Local	
Return header pressure	Local	
Supply and return header differential pressure (Calculated in control system)	Control room	Used for closed circuit pressure control.
Closed circuit head tank level	Local and Control Room	Used to control the closed circuit make-up
Closed circuit supply header temperature	Control Room	Used for cooling water temperature control.
Open circuit return temperature	Local and Control Room	
Cooling Tower outlet temperature	Local and Control Room	
Open circuit return temperature	Local and Control Room	
Closed circuit flow Supply/Return flow	Local and Control Room	
Closed circuit recirculation flow	Local and Control Room	
Open circuit return flow	Local and Control Room	
Open circuit recirculation flow	Local and Control Room	
Control Valve position	Control Room	Provide an indication of the correct functioning of the system/valve
Open circuit make-up flow	Local and Control Room	Water accounting
Closed circuit make-up flow	Local and Control Room	Water accounting
Blowdown Flow measurements	Local and Control Room	Water accounting
Open circuit conductivity	Local and Control Room	Blow down control
Fan vibrations	Local and	

Measurement	Indication	Reason
	Control Room	
Fan gearbox bearing temperature	Local and Control Room	
Fan gearbox oil level	Local and Control Room	

The modern tendency is to use indicating transmitters for most of the measurements. Older control systems are unable to handle the amount of input and therefore used transmitter only for the important measurements and switches and gauges for the rest. Switches are still used in hardwired protection systems.

Each individual pump must be equipped with a suction and discharge pressure transmitter with local indication.

Flow measurements need to be included to comply with the "Water Accounting Directive" [59]. The requirements for flow meters are described in the document and these shall be applied in the design to measure water streams.

The selection and positioning of flow meters needs to consider the availability of straight lengths of pipe without any pipe components, for accurate measurement of the flow.

5.18.3 Alarm Management

Alarm Management System Guideline[39]specifies the principles, rationale, process and resources required to ensure that effective alarm management systems are implemented and maintained at all Eskom Power Plants. A "(process) alarm is a mechanism for informing an operator of an abnormal (process) condition for which an operator action is required. The operator is alerted in order to prevent or mitigate process upsets and disturbances." The following are typical alarms for cooling water systems.

Table 11: Typical system alarms

Alarm	Reason	Possible causes
Pump suction pressure low alarm	Protect the pump from cavitation	Closed suction valve; Low supply water level
Pump discharge pressure High alarm	Protect pump from overheating	Closed discharge valve.
Strainer/Filter Pressure drop high	High suction head	Filter blocked or dirty
Low flow	Warning that the users are not receiving the water they require	Blocked piping; Dirty strainer Partially closed valves.
Closed circuit head tank level high	Warning that the tank will potentially overflow	The make-up system has not stopped
Closed circuit head tank level low	Warning that the pressure in the system will fall	Leaks from the system Make-up system failed
Cooling Tower Sump water level low	Warning that open circuit pump will trip on low suction pressure	Leaks from the system; Make-up system failed to start
Cooling Tower Sump water level high	Warning that the sump will potentially overflow	Make-up system failed to stop
Closed circuit supply temperature high	Warning that cooling of users will stop.	Failure of system

Alarm	**Reason**	**Possible causes**
Closed circuit supply temperature low	Warning that users will to overcooled	Failure of temperature control. To many cooling towers in operations
Instrument fault	Warning that the information supplied by the instrument is no longer available	
Electrical fault on drives (pumps and valves)	Warning that the equipment has stop working	
Drive trip	Warning that the equipment has stop working	

5.18.4 Plant protection

Equipment needs to be protected against damage or to prevent an unsafe situation.

Table 12: Typical plant protections

Trip	**Action**	**Possible causes**
Pump suction pressure low	Trip pump	Closed suction valve; Low supply water level
Pump discharge pressure High	Trip pump	Closed discharge valve.
Drive fault	Trip Drive	Electrical fault

5.19 RELIABILITY AVAILABILITY AND MAINTAINABILITY

The standard definition of Reliability is the probability of zero failures over a defined time interval (or mission). The reliability of any system is equal to the product of the reliability of its components, or the so-called weakest link concept.

Availability is defined as the percentage of time a system is considered ready to use when tasked. When dealing with the availability requirement, the maintainability requirement must also be invoked as some level of repair and restoration to a mission-capable state must be included. One can see how logistics and logistic support strategies would also be closely related and be dependent variables at play in the availability requirement. This would take the form of sparing strategies, maintainer training, maintenance manuals, and identification of required support equipment.

Maintainability is a measure of the ease and rapidity with which a system or equipment can be restored to operational status following a failure. Maintainability is the parameter concerned with how the system in use can be restored after a failure, while also considering concepts like preventive maintenance and Built-In-Test (BIT), required maintainer skill level, and support equipment.

Auxiliary cooling systems normally form part of a chain of systems that need to function as a complete system. The whole chain of system needs to be evaluated in terms of RAM. The chain includes the power supply (including power supply to all the elements in the chain), control system, water supply, open cooling system, closed cooling system and the users. Special attention needs to be given to the power supply to each element of the chain. A "train" type of concept needs to be followed

The following can be considered to improve the Reliability, Availability and Maintainability:

5.19.1 RAM consideration in cooling tower design

- Divide cooling towers in separate isolatable cells. The cooling tower must be designed to provide the design heat transfer with a minimum of 25% of the cells isolated.

- Consider civil engineering constrains when making decision on number of Towers specified

5.19.2 RAM consideration in pumping and piping design

- Provide redundant pumps. Redundancy of pumps can be based on 2 x 100% or 4 x 50%. These selections are based on the two separate electrical supply boards available for the equipment. Redundancy of 3 x 50% will allow for only 50% pump capacity when one of the electrical boards is out of service for maintenance.
- Provide bypasses around flowmeters and control valves
- Placement of suitable valves for isolation of equipment for repair, without influencing other operating units.
- Draining and venting valves on pipework and equipment at low and high points in system pipework. Draining the pipe system. Valves should be positioned at all low points to ensure drainage of systems for commissioning and maintenance.
- The positioning of valves for operability, isolation and maintainability.

5.19.3 RAM consideration in power distribution

- Provide power from different sources
- Automatic switch-over of equipment

5.19.4 RAM consideration in layout and civil design

- Equipment to be easily reached from ground level or appropriate platforms.
- Lifting beams or cranes to be available for removing and installing of equipment.
- Spare parts lists and sub-assemblies to be available for systems.

5.20 ARRANGEMENT DESIGN

The arrangement of equipment needs to be considered at all the stages of the design process. An integrated approach needs to be followed where the requirements for all the disciplines are considered and documented. The level of detail increased as the design progresses through the different design stages. The following items need consideration:

- Overall site layout and building structures (including foundations);
- Positions of equipment;
- Position pumps as close as possible to the water source;
- Avoid local high points in pump suction lines;
- Position of electrical switchgear and control cubicles relative to the associated equipment (motors, actuators, instrumentation etc.);
- Pipe routes and servitudes;
- Pipe slopes;
- Cable routes, junction boxes and servitudes for electrical, C&I, IT and Communication services;
- Ancillary services (HVAC, small power and lighting, fire protection, service air, etc.)
- Accessibility to plant and equipment (refer to section 5.21 for more detail);
- Lifting equipment;

- Drainage;
- Fire barriers.
- Consider that very big pipe sizes which does not give flexibility for pumps or Cooling Tower positioning.
- Maintenance access to remove heat exchanger plates for cleaning or in the case of shell and tube to remove end plates and have access for tube cleaning

Servitudes need to be defined of all equipment and services.

5.21 ACCESSIBILITY TO PLANT AND EQUIPMENT

Access to and from the plant need to be considered at all stages of the design process. Access routes and working areas must be indicated on layout and arrangement drawings. The following need to be considered:

- Emergency egress conforming to the SANS Standards [13] and Eskom Specification [2].
- Access for operational activities.
- Access for maintenance activities. This must include the necessary maintenance routes for removal of equipment.
- Access for construction activities.
- Access for testing and inspections (during the initial construction as well as during the operational phase of the Plant).

Accessibility of all equipment is preferred at ground level for operation and maintenance. Ladders and platforms when needed, shall comply with the requirements of the OHSA act [1].

The lifting of heavy equipment shall be identified and the necessary Crawl beams and hooks to be provided

5.22 INTERFACE DESIGN

The interface between systems and/or portions of systems designed by different Design Authorities must be identified during the concept design and must be finalised during the process design.

5.22.1 Mechanical/Process

The following items are relevant to the mechanical/process interface

- Design codes
- Process data
- Water supply curve and system resistance curve
- Consolidated hydraulic model
- Forces at interface
- Flexibility/support/anchoring at interface
- Connection detail i.e. flange, threaded or welded. The full specification of the connection must be provided.
- Geographical coordinates of interface

5.22.2 Electrical interface

Motors, actuators standalone control systems are normally supplied as part of the mechanical equipment. The items must however be incorporated into the overall electrical system. The following items are relevant to interface:

- Electrical load requirements;
- Method of control;
- Geographical coordinates of interface;
- Termination detail;
- Direction of entry;

5.22.3 C&I

Instruments that are needed for control shall be supplied with the appropriate connections for signal delivery to the control system. These instruments can be classified as inline instrumentation or not. Inline instrumentation forms an integral part of the piping system (e.g. flowmeters). Non inline instrument obtain information from the system through a tapping point (e.g. pressure, and temperature transmitters). The following needs to be considered:

- Mechanical connection type;
- Connection configuration (e.g. pressure tapping point on the side of the pipe);
- Termination detail for inline instruments;
- Geographical coordinates of interface.

5.22.4 Civil

The following needs to be considered:

- Static and dynamic forces (magnitude, direction and position);
- Attachment detail (cast in plates, anchor bolts etc.);
- Vibrations;

6. EQUIPMENT SELECTION

The following need to be considered when selecting equipment;

- Standardisation (including with existing plant and other systems)
- Functionality
- Reliability
- Operability
- Maintainability
- Capital cost
- Life cycle cost
- Noise levels
- Environmental conditions
- Corrosion resistance

Demineralised is used in closed circuits. The demineralised water is treated to prevent corrosion of the components. It is however important that the material used are compatible with the treatment regime used. In general copper and aluminium components cannot be used unless the demineralised water is treated for use with these materials.

The following sections describe the general requirements for equipment selection. Appendix B contains specific requirement for most common cooling water systems on a power station. These specific requirements are aimed at new plants. For modifications to existing plant it is important to select equipment which complies with the same standards as the equipment in the existing plant.

The schedules in Annexure B can be included in contracts where the detail design is done by a Contractor. The schedules however have to be adapted for the specific plant.

6.1 PIPING COMPONENTS

The lists below indicate commonly used piping component standards applicable for cooling water systems. The standards recommended for new installation are indicated by a comment in brackets. It is however important that the designer consider the standards used on the existing installation when designing modification.

Carbon steel

- Piping:
  - SANS 62-1 Steel Pipes Part 1: Pipes suitable for threading and of nominal size not exceeding 150 mm.(Recommended for above ground piping smaller or equal to 150 NB);
  - SANS 719 Electric welded carbon steel pipes for aqueous fluids (large bore) (Recommended for above ground piping larger than 150 NB);
  - ASME B36.10M, Welded and Seamless Wrought Steel Pipe;
- Carbon steel fittings:
  - SANS 14 (ISO 49), Malleable cast iron fittings threaded to ISO 7-1
  - SANS 62-2, Steel Pipes Part 2: :Screwed pieces and pipe fittings of nominal size not exceeding 150 mm.(Recommended for above ground piping smaller or equal to 150 NB);
  - BS EN 10253, Butt welding pipe fittings Part 1: Wrought carbon steel for general use and without specific inspection requirements;
  - BS EN 10253, Butt welding pipe fittings Part 2: Non alloy and ferritic alloy steels with specific inspection requirements
  - JIS B 2304, Steel butt-welded pipe fittings for ordinary use
  - ASME B16.9, Factory-Made Wrought Steel Butt welding Fittings
  - Fabricated fittings (e.g. Mitre bends) must comply with the design code used.
- Carbon Steel Flanges
  - SANS 1123, Pipe flanges (Recommended for new installations)
  - BS EN 1092-1, Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN designated Part 1: Steel flanges
  - ASME B16.5, Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard [38] (Not preferred).

6.2 VALVES

A valve is a piping component which influences the fluid flow by opening, closing or partially obstructing the passage of fluid flow or by diverting or mixing the fluid flow.

A valve list needs to be completed as well as the Valve Specification sheets particular to each type and size valve by the designer of the system.

The system designer will note that the different SANS and International Valve Standards have sections which need to be completed by the Purchaser/Designer.

Valves serve the following purposes:

- To isolate one section of pipe work from another for maintenance (Isolating valves)
- To control if flow to a system or tank is possible or not (On-Off valves)
- To control the rate of flow (throttling valve)
- To control the upstream or downstream pressure (pressure regulating/sustaining valves)
- To prevent reverse flow (check valves)
- To prevent the pressure from exceeding a certain maximum value (Pressure relief valve or bursting disc)
- To remove air from fluid systems (Air release valve)

Generally, valve sizing is based on the standard thermodynamic laws of fluid flow. The application of these laws is affected by the particular function of the valve plus the type and severity of the service. Simple on–off block valves are expected to pass nearly 100 percent of the flow without a significant pressure drop, since they are not expected to control the flow other than to shut it off. On the other hand, throttling services are expected to produce a certain amount of flow at certain positions of opening and take a particular pressure drop. Therefore, the science of valve sizing is almost always directed toward sizing throttling valves.

The Designer should also review the information available from manufacturers and valve suppliers.

Basic types of valves are distinguished by the operating motion of the obturator/disc and the direction of flow in the seating area

6.2.1 Types of valves related to function

6.2.1.1 Isolating valves

With isolating valves, the valve is often expected to pass full flow. If the valve's internal flow passage or closure element is sized smaller than the upstream piping, flow will be restricted from that point forward. This will cause the valve to take a pressure drop and pass less flow, defeating the major purpose of the on–off valve. If the on–off block valve is sized larger than the upstream piping, installation costs are more expensive (since increasers are required). The larger valve is also more expensive. The basic function of manual on–off block valves is quite simple: to pass full flow while the valve is open or to shut off or divert the full flow when closed. Therefore, the valve size can sometimes be determined simply by the size of the piping, which has already been sized by the designer. Valve manufacturers often provide sizing charts that indicate the relationship between the flow-rate requirement (Q) are the minimum and maximum valve size that can pass the given flow rate.

An important choice in isolating valve sizing is whether the valve should be full bore or reduced bore. In many cases this is more a function of the valve's purpose to pass full flow or to take a slight pressure drop. If the valve is installed in an application that must allow the passage of a pig to clean or scour the pipeline, the valve chosen must be full bore, since the pig is the same size as the inside diameter of the pipe. Another application calling for full-bore manual valves is one installed in slurries or services with entrained materials or particulates. If the valve has a reduced bore, these particulates or slurries have a tendency to settle and become trapped at the narrowed constriction. A full-bore valve has no such restriction, allowing for free passage of the foreign material without collection. Full-bore manual valves are also chosen for services with high velocities, for which a restriction would increase the chance of erosion as well as increase the velocity further.

The service conditions generally required for correct manual-valve sizing are maximum and minimum temperatures, pressures, flow rates, and specific volume. Not only are the extremes important, but also the average operating conditions are important.

The valves are mostly manually operated. Locking functionality must be provided for isolating valves.

6.2.1.2 On-Off valves

On-off valves are similar to isolating valves but are operated more frequently. On-off valves normally also perform the function of an isolating valve. They are mostly actuated to allow for control by the controlling system.

6.2.1.3 Throttling valves

Normally a power operated device which changes the fluid flow rate in the process control system. It consists of a valve connected to an actuator with or without positioner that is capable of changing the position of the obturator in the valve response to a signal from the controlling system. The signal from the controlling system can be based on a pressure, flow, level etc.

The control/throttling valves, which are intended to take a pressure drop and to reduce the flow, may have a seat that is significantly less in diameter than the upstream port. Determining the flow through this diameter is the science behind valve sizing. If a throttling valve is sized too small, the maximum amount of flow through the valve will be limited and will inhibit the function of the system. If a throttling valve is sized too large, the user must bear the added cost of installing a larger valve. Another major disadvantage is that the entire flow control may be accomplished in the first half of the stroke, meaning that a minor change in position may cause a large change in flow. In addition, because regulation occurs in the first half of the stroke, flow control is extremely difficult when the regulating element is operating close to the seat. The ideal situation is for the throttling valve to utilize the full range of the stroke while producing the desired flow characteristic and maximum flow output.

Throttling valves are rarely undersized, because of the number of safety factors built into the user's service conditions and the manufacturer's sizing criteria. Because of these safety factors, a large number of throttling valves actually end up being oversized. This happens because the user provides a set of service conditions that are usually the maximum conditions of the service (temperature, pressure, flow rate, etc.). The manufacturer then adds its own safety factors into the sizing equations. The valve manufacturer does this to avoid the error of under sizing, which is less forgiving than oversizing. Although not ideal, an oversized valve is still workable. When calculated properly, C_v determines the correct trim size (or area of the valve's restriction) that will allow the valve to pass the required flow while allowing stable control of the process throughout the stroke of the valve.

Throttling valves require a systematic method of determining the required flow through the valve, as well as the size of the valve body, the body style, and materials that can accommodate (or tolerate) the process conditions, the correct pressure rating, and the proper installed flow characteristic. The industry standard for determining the flow capacity of a throttling valve is ANSI/ISA Standard S75.01, which contains the equations required to predict the flow of incompressible (liquid) and compressible (gas) process fluids. Because of the compressibility issues between liquids and gases, equations have been formulated for each and are included in this chapter.

Proper selection of the valve is based on the service conditions of the process. For correct sizing, the following conditions are needed: the upstream pressure; the maximum and minimum temperatures; the type of process fluid; the flow rate that is based upon the maximum flow rate, the average flow rate, and the minimum flow rate; vapor pressure; pipeline size, schedule, and material; the maximum, average, and minimum pressure drop; specific gravity of the fluid; and the critical press.

With liquid applications, when the fluid passes through the narrowest point of the valve (vena contracta), the pressure decreases inversely as the velocity increases. If the pressure drops below the vapor pressure for that particular fluid, vapor bubbles begin to form. As the fluid moves into a larger area of the vessel or downstream piping, the pressure recovers to a certain extent. This increases the pressure above the vapor pressure, causing the vapor bubbles to collapse, or implode. This two step-process; creation of the vapor bubbles and their subsequent implosion, is called cavitation and is a leading cause of valve damage in the form of erosion of metal surfaces.

As the pressure drops, the point where vapor bubbles begin to form is called *incipient cavitation.* The pressure level where cavitation is occurring at its maximum level is called *advanced cavitation.* During advanced cavitation, the flow is choked and cannot increase, which affects the flow capacity of the valve as well as its function. The point where advanced cavitation occurs can be predicted.

The flow capacity of a valve may be affected by nonstandard piping configurations, such as changes in pipe diameter, which must be corrected in the C_v equation. Designers should also read relevant literature on the sizing of these valves.

6.2.1.4 Pressure regulating/sustaining valves

These valves control the downstream/upstream pressure by hydraulic means without the necessity of a control system. These types of valves are suitable for remote locations.

6.2.1.5 Check Valves/Non Return Valve

A valve that automatically opens by fluid flow in a defined direction and which automatically closes to prevent fluid flow in the reverse direction.

The most critical element of check-valve sizing is that a sufficient pressure drop and minimum flow exist for the check valve to open. Without a pressure drop, the closure element will not open and the valve will remain closed, which is what happens when a pump fails to maintain a proper flow or flow reverses.

The minimum pressure drop (cracking pressure) required for check valves to open is typically available from standards or the suppliers of check valves. This minimum pressure drop is needed to maintain the open position of the closure element without failing. If the pressure drop falls to below the minimum pressure drop, the closure element will float back and forth, which is commonly called "flutter." As the disk moves toward the seat, the opening narrows and pressure rebuilds, which causes the disk to open higher. This low-pressure drop situation will cause this cycle to repeat until the pressure drop is increased, causing wear of the moving parts and shortening the life of the check valve. The maximum pressure drop is depending on the size of the check valve. Higher pressure drops lead to severe erosion of the check valve's closure element.

The cracking pressure can be important if the valve is installed in a vertical line, where the check valve must open against gravitational forces in addition to the process pressure. Smaller lines have higher cracking pressures than larger lines. This is because the larger the line, the larger the process force must be against the component's mass in the check valve.

Unless the flow experiences a wide range of flow during the service, check valves are sized for minimum flow, which in turn determines the valve size. This is done using manufacturer's sizing charts. If the size provided for the minimum flow is equivalent to or greater than the pipeline size, the pipeline size should be used for the valve size. For example, if the manufacturer's literature calls for a 100 mm check valve, yet the pipe size is 75 mm line, a 75 mm check valve should be satisfactory. The larger, oversized valve will not benefit the flow rate, yet is more expensive and would require the installation of increasers. If the suggested valve size for the minimum flow is smaller than the pipeline, reducers must be installed and the smaller-sized check valve installed.

The user should ensure that the flow rates are within the parameters of the check-valve design. High flow rates can increase the frequency of vortices and currents, which will increase the pressure drop across the valve as well as cause valve wear. Insufficient flow will cause the valve to flutter. The flow must be sufficient to overcome the closed position of the check valve—whether it is gravity, weight of the closure element, line orientation, or spring force.

As a general rule, the maximum liquid flow velocity for check valves is 3.4 m/s. The minimum liquid flow velocity is normally 1.8 to 2.1 m/s, although some designs (such as a double-disk check valve) can operate at 0.9 m/s.

6.2.1.6 Pressure Relief Valves

Valves which automatically, without the assistance of an energy other than that of the fluid concerned, discharges a certified quantity of fluid so as to prevent a predetermined safe pressure being exceeded and which is designed to reclose and prevent further flow of fluid after normal pressure conditions of service has been restored.

6.2.1.7 Air release valve and Vacuum breakers

Air release valves function to release air pockets that collect at each high point of a full pressured pipeline. An air release valve can open against internal pressure, because the internal lever mechanism multiplies the float force to be greater than the internal pressure. This greater force opens the orifice whenever air pockets collect in the valve. Air Release Valves are essential for pipeline efficiency and water hammer protection.

A Vacuum breaker valve, or Air Vacuum Valve is a safety valve opening inward to admit air to a pipe in which the pressure is less than that of the atmosphere, in order to prevent collapse of the pipe

Air Release and Combination Air Release Valves help protect systems from air lock and collapse by eliminating excess air or admitting air before a vacuum condition can occur. They not only help the system maintain its design capacity that could be impacted if entrained air is present in the pipeline, they are also a critical to reliable and safe pump start-up and stopping operations.

6.2.2 Types of valves related to design

6.2.2.1 Gate valve

A valve in which the obturator movement is linear and in the seating area, at right angle to the direction of flow.

6.2.2.2 Globe valve

A valve in which the obturator movement is linear and in the seating area, in the direction of flow. This definition also applies to lift check valves and axial check valves

6.2.2.3 Plug and Ball valves

A Valve in which the obturator rotates about the axis at right angle to the direction of flow and in the open position, the flow passes through the obturator.

6.2.2.4 Butterfly valve and eccentric Plug valve

A Valve in which the obturator rotates about the axis at right angle to the direction of flow and in the open position, the flow passes around the obturator. This definition also applies to swing check valves.

6.2.2.5 Diaphragm valve

A valve in which the fluid flow passage through the valve is changed by deformation of a flexible obturator. This definition also applies to diaphragm check valves.

6.2.3 Valve Standards

The following standards are applicable to valves used in Cooling Water systems:

- BS EN 736 Part 1 to 3 Valves Terminology
- BS EN 1171 Industrial valves - Cast iron gate valves
- BS EN 12288 Industrial valves - Copper alloy gate valves
- BS EN 13397 Industrial valves - Diaphragm valves made of metallic materials
- BS EN 13789 Industrial valves - Cast iron globe valves
- BS EN 1983 Industrial valves - Steel ball valves
- BS EN 558 Industrial valves — Face-to-face and centre-to-face dimensions of metal valves for use in flanged pipe systems — PN and Class designated valves
- SANS 1056-1 Ball valves Part 1: Fire-safe valves
- SANS 1056-2 Ball valves Part 2: Heavy duty valves (not fire-safe)
- SANS 1056-3 Ball valves Part 3: Light duty valves (not fire-safe)
- SANS 1551-1 Check valves (flanged and wafer types) Part 1: PN series
- SANS 1808-13 Water supply and distribution system components: Part 13: Diaphragm valves
- SANS 1849 Butterfly valves for general purposes
- SANS 191 Cast steel gate valves
- SANS 664-1 Wedge gate and resilient seal valves for waterworks Part 1: General
- SANS 664-2 Wedge gate and resilient seal valves for waterworks Part 2: Wedge gate valves
- SANS 664-3 Wedge gate and resilient seal valves for waterworks Part 3: Resilient seal valves
- SANS 665-1 Wedge gate and resilient seal valves for general purposes Part 1: General
- SANS 665-2 Wedge gate and resilient seal valves for general purposes Part 2:
- SANS 665-3 Wedge gate and resilient seal valves for general purposes Part 3: Resilient seal valves

6.3 PUMPS

Single stage centrifugal pumps are normally used in cooling water systems. Multi stage pumps can be considered when a high pump total head is required.

The performance of pumps is defined by the pump curves, which is available from the pump supplier, usually shown by graphs which refer to flow rate, the head (pressure), efficiency, shaft speed, and the required net positive suction head ($NPSH_R$) for various impellor diameter sizes. The intersection between the pump curve and the systems resistance curve are the duty point of the pump. The $NPSH_R$ is an important characteristic and should be less than $NPSH_A$ for the selected pump installation.

The Pump Laws can be used to extrapolate curves for higher and lower speeds within the design limits of the pump.

The Eskom Specification for centrifugal pumps (240-560 30558) shall be adhered to the other specification/standards applicable to Centrifugal pumps are:

- BS EN 733 End-suction centrifugal pumps, rating with 10 bar with bearing bracket. Nominal duty point, main dimensions, designation system
- BS EN ISO 2858 End-suction centrifugal pumps (rating 16 bar). Designation, nominal duty point and dimensions
- BS EN ISO 9906 Rotodynamic pumps. Hydraulic performance acceptance tests. Grades 1, 2 and 3
- BS ISO 10816-1 Mechanical vibration. Evaluation of machine vibration by measurements on non-rotating parts. General guidelines
- BS ISO 10816-7 Mechanical vibration. Evaluation of machine vibration by measurements on non-rotating parts. Rotodynamic pumps for industrial applications, including measurements on rotating shafts

6.4 FANS

The following standards are relevant to cooling tower fans:

- BS EN ISO 5801, Industrial fans - Performance testing using standardized airways.
- ANSI/AMCA 210, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating

6.5 COUPLINGS

Pumps and fans can be direct driven or connected with a coupling to a motor. The coupling should be covered to prevent exposure to rotating items.

The most common couplings for pump are rubber couplings. Couplings to be suitable for pump start-up torque.

6.6 GEARBOX

When fan gearboxes are required the following will apply:

- Oil level monitoring and alarm
- High temperature alarm
- Vibration.
- Oil seals
- Cooling required
- Orientation of input and output shaft

6.7 TANKS

Tanks shall be designed according to applicable guides, codes and standards. All required nozzles for inflow, outflow, breathing, cleaning, overflow etc. needs to be specified as well as the requirements for manholes for inspection and cleaning.

When specifying the volume of a tank it is important to specify the working volume of the tank and not only the total volume.

Applicable Codes and Standards to be selected for design, fabrication and construction of tank suitable for cooling water systems:

- SANS 10329, The design and construction of sectional steel tanks for storage of liquids at or above ground level
- BS EN 14015, Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above

- SANS 53121, GRP tanks and vessels for use above ground

Tank bases and supports are to be designed according to the applicable Eskom Civil Standards.

6.8 STRAINERS AND FILTERS

Strainers and filters are used to remove particle in order to protect equipment and prevent blockages.

Strainers and filters add extra pressure drop to the system and for design pressure the dirty resistance need to be taken into account

A proper mesh size shall be selected for protection of the pump impellor and other downstream equipment like nozzles and sprays.

Strainers should be easily cleanable and not required to stop the system from operation. Self-cleaning strainer should be considered in case where the cleaning frequency is too high. The acceptable frequency will depends on the station maintenance strategy, location of the strainer and criticality of the system.

Pressure drop will be measured over strainers and filters to indicate cleaning required.

It is recommended that duplex filters and strainers are installed in water systems.

6.9 BREATHERS

Breathers are used on tanks and vessels to prevent particles from entering while allowing for ingress or exhaust of air as levels move between minimum and maximum. Silica gell or dryer to be utilised for tanks with corrosive fluids. Breathers can be protected by a mesh to prevent ingress of birds, rodents and insects.

6.10 HEAT EXCHANGERS

Heat exchangers shall be designed by manufacturers as pressure vessels and will be subject to compliance to OHSA regulation and categorisation of SANS 347.

The main heat exchangers installed between closed and open circuit to be plate heat exchangers preferably single pass to limit pressure drop. The plate heat exchangers shall be constructed from stainless steel grade 304.

The heat exchanger between the closed circuit auxiliary cooling system and end user systems are usually shell and tube type

When connecting to pipe work system, suitable isolation of dissimilar materials shall be provided to avoid galvanic corrosion. The plate pack shall be assembled between fixed frames and compressed by tightening bolts. The plates shall be fitted with gaskets which shall seal the interpolate channel. The plate corrugation shall promote fluid turbulence and shall support plates against differential pressure.

Vents and drains will be supplied from each heat exchanger

6.11 MOTORS

The following factors needs to be considered when specifying the requirements for a pump motor:

- Worst possible service condition. For a centrifugal pump this is normally at pump run out conditions (high flow, low pressure);
- Hydraulic power required for maximum pump impeller diameter under run-out conditions.
- Pump/Fan efficiency;
- Coupling efficiency;
- Gearbox efficiency.

The following Specification and Standard apply:

- 240-57617975 Procurement of Power Station Low Voltage Electric Motors Specification Standard
- 240-50237155 New MV Motor Procurement Standard

6.12 VARIABLE SPEED DRIVE (VSD)

A variable speed drives are used in the cooling Tower fans motors to control the cooling water temperature.

VSD’s can be used on the cooling water pumps for an additional capacity control or for saving in electricity consumption

There may be additional requirements with regard to electrical and mechanical components for motors to be used with variable speed drives or at nuclear sites or specialized operating systems and environments. The standard elements of this reference should, however, still be applicable and useful to specialized motors. It is understood that some elements of this specification may be adapted and additional information added through the scope of work for specialized motors and applications

The Designer will at an early stage in the project discuss all Electrical related design aspects with the appointed Electrical designer. The location of the VSD needs to be considered. A cubicle with a suitable IP rating needs to be supplied in cases where the VSD needs to be located in the pump area. This will be required when switchgear room is too far from the motor or when there is no space in the switchgear room.

6.13 CONTROL EQUIPMENT

The control of Cooling Water systems are normally controlled by the station control system. The selection of the control equipment falls outside the scope of this document.

In some cases a local control system, which is supplied with the mechanical equipment, is required. In these cases the Mechanical Designer needs to determine the requirements with the input from the C&I Designer at an early stage of the design process.

6.14 INSTRUMENTATION

Instrumentation is needed for the proper commissioning and operation of the plant system. These instruments can only be available at the point of installation or can also provide an impulse for readout and control.

Instruments required can be:

6.14.1 Flow Measurement

Fluid flow devices fall into a number of device categories as well as fluid classes. In general we can split the fluids into two classes; gasses and liquids. Within these two broad classes are a number of special classes that one should be careful of

When selecting a transducer you should be cautious that the device you are selecting is compatible with the fluid and conditions you are working with.

Flow measuring instruments usually needs straight lengths of piping before and after the instrument. The accuracy of measurement is dependent on a uniform flow.

All flow meters to be capable of providing actual flow rate as well as totalising over a time period. The accuracy for instruments can be ±2% except in metering for payment the accuracy of ±0.5% is required.

BS ISO 11631:1998 Measurement of fluid flow — Methods of specifying flowmeter performance.

Different type of flow meters is available

6.14.1.1 Electromagnetic

If an electrical conductor is moved in a magnetic field which is perpendicular to the direction of motion and to the conductor, an electrical voltage is induced in the conductor whose magnitude is proportional to the magnetic field strength and the velocity of the movement. This characterization of the laws of induction also applies to the movement of a conductive liquid in a pipe through a magnetic field. An additional requirement for the operation has already been mentioned, namely the fact that the measuring medium must be an electrical conductor. Therefore a minimum conductivity between 20 and 0.05 µS/cm is required, depending on the device type. Austenitic steel does not hinder the magnetic field; therefore it is the most commonly used material for the meter pipe in the electromagnetic flowmeter.

This type of meter is preferred in all water applications except for demineralised water.

These meters are also suitable for reverse flow.

6.14.1.2 Ultra sonic

The sound velocity which is a material property value is the propagation velocity of a sound wave in a medium. It changes with the density of the measuring medium. Therefore it is temperature dependent in liquids and pressure and temperature dependent in gases. When a sound impulse is transmitted from location A it arrives at a second location B with the velocity of sound at time:

This type of meter is preferred in demineralised water applications.

6.14.1.3 Pitot tube

The Pitot tube is a simple device that allows for the measurement of the flow pressure in a moving fluid. This device is a section of tube that measures the pressure at the tip and the pressure at the side of the tube. Reading this differential pressure and applying Bernoulli’s equation will allow for the calculation of the fluid velocity.

6.14.1.4 Moving Member Meters

This is another method of measuring the flow velocity in a duct or pipe is the special class of transducers called “moving member” meters. These fall into two primary classifications, turbines and paddlewheels. Both of these measure the velocity of the fluid in the tube or duct. What makes them different from other velocity measurement devices is that they employ a moving element to determine the flow, unlike the Pitot tube and hot wire probes.

The axial type turbine flow meter consists of a circular housing with a suspended blade system. This suspended blade is mounted on a shaft or bearing at the centre of the housing. As fluid flows past the blades, they are rotated by the fluidic forces. This type of flow meter has excellent accuracy in both liquids and medium velocity gasses. Since the accuracy of the meter depends on the speed of the impeller, it is imperative that the bearing system that supports the blade remain clean and free to turn. This tends to limit the fluids to “clean” fluids that do not contain significant numbers of abrasive particles.

Radial Turbine Flowmeter is an axial style turbine flowmeter that works well for smaller diameter pipes and ducts. If you have an application in a significantly larger pipe or duct, an alternate configuration will be required. In this alternate style device, a small turbine device is inserted in through the side of the pipe, and the flow across the turbine blades generates a measurement related to the general flow in the pipe, hence the common name of “insertion Turbine flow meter.”

Paddle wheel flowmeter is a lower cost alternate to the turbine flowmeter. This device is somewhat similar to the insertion type turbine flowmeter, but instead of a turbine blade with the flow generating lift forces to cause the rotation, the paddle wheel is perpendicular to the flow and rotates much like an old fashioned steam boat paddlewheel. These devices are usually inserted into a specially made tee in the flow line.

6.14.1.5 Obstruction type

The differential pressure flowmeters are very sensitive to disturbances. Long, disturbance-free straight pipe sections should provide for equilibration. Disturbed flow profiles in turbulent flows must be considered independently of the device type.

Orifice (The primary disadvantage of the orifice type flow meter is that there is a significant pressure drop across the plate, which is not recoverable. For this reason selection of this meter must only be used where you can afford the pressure drop without affecting the rest of the system operations.

Venturi - The Venturi flow meter, while considered an obstruction flow meter, is less of an obstruction than the orifice type. It still does have a certain amount of pressure drop, but it is significantly less than the orifice type meter.

Nozzle Flow meter- A flow nozzle consists of a restriction with an elliptical contour approach section that terminates in a cylindrical throat section. Pressure drop between the locations one pipe diameter upstream and one-half pipe diameter downstream is measured. Flow nozzles provide an intermediate pressure drop between orifice plates and venturi tubes; also, they are applicable to some slurry systems that would be otherwise difficult to measure.

6.14.1.6 Variable Area flowmeters

The rotameter is a variable area meter that employs a vertical tube of varying diameter, with an object inserted in it. This object is known as the float. This type meter is used only in a vertical position, as gravity is a primary force involved in the calibration the device. These meters can be glass tube or metal tube.

6.14.2 Pressure measurement

Pressure can be measured in absolute, gauge, vacuum or differential pressure. Absolute pressure is referred to absolute zero. Gauge pressure is the measure between the inside of the equipment and the direct surrounding atmosphere. Pressure differential is measured across equipment for indication of operating condition. The majority of instruments employ pressure to deflect an electronic pressure sensor, elastic element. Bourdon tube, diaphragm or bellows

An important part of pressure transmitter selection is ensuring that any instrument used is compatible with type of water. A pulsation damper will be provided to give a stable indication

The instrument can be a combination of a local indicator and transmitter or just a pressure gauge for local read-out.

The range of the gauge and transmitter will be determined by the highest and lowest of the static or dynamic pressure of the system. Normal operating will preferably be in the middle of the range.

The Pressure Measurement Systems Installation Standard [41] covers the minimum requirements for the installation of all pressure transmitters and associated equipment.

6.14.3 Temperature measurement

The temperature method used is based on the temperature range and on accuracy and repeatability.

A differentiation is made between contacting temperature measurement methods and non-contacting measurement methods. The contacting measurement methods, which are dominant in industrial temperature measurement technology, can be further subdivided into mechanical and electrical contacting thermometers.

Different types of measuring instruments are available

- Thermocouples which are suitable for most water system applications
- Mechanical Thermometers (liquid filled). These are used where only read-out at the specific location is required
- Indicator thermometers using either bimetal, liquid filled etc. can also be used in the field.
- Resistance Thermometers with Metal Resistors and semiconductor elements
- Non-contacting Temperature Measurement i.e. Infrared/radiation

The Temperature Measurement Systems Installation Standard covers the minimum requirements for the installation of temperature instrumentation [42].

6.14.4 Conductivity measurements

The instrument measuring conductivity of water is installed in the open circuit return water line to establish concentration of salts in water and to determine frequency of the open circuit blowdown.

The types of instrument used have to be determined by C&I specialists.

6.15 ACTUATORS

Actuators are usually supplied with the particular equipment being actuated and shall be of sufficient motor torque to open and close valves at the desired speed. The fail safe position needs to be specified where applicable.

Preference is given to electrical actuation, solenoids for small pipe sizes and electrical actuators for larger pipe sizes.

7. ACCEPTANCE TESTS

Tests and inspections are necessary to verify and validate that the system are fulfilling the intended purpose to an acceptable quality level. The design must be such that it is possible to perform the required tests and inspections. The following sub-sections describe the performance tests required before it is delivered to site as well before the plant is accepted on site. These subsections are not intended to list all the required tests and inspections for validation and verification purposes. All applicable codes and standards need to be consulted when compiling the quality control plan for the implementation of the design.

The performance test results are interpreted by the designer via plant simulated analysis and confirmed that the design parameters are met.

7.1 FACTORY ACCEPTANCE TESTS

The following are the minimum requirements for factory acceptance tests:

- Pump and motor vibration tests according to BS ISO 10816
- Pump hydraulic performance acceptance tests according to BS EN ISO 9906;
- Cooling tower fan tested and certified in terms of BS EN ISO 5801 or ANSI/AMCA 210

7.2 SITE ACCEPTANCE TESTS

The following are the minimum requirements for site acceptance tests:

- Pump and motor vibration tests according to BS ISO 10816
- Confirm pump duty point;
- Confirm flow rate to each user;
- Confirm pressure at each user;
- Confirm fan duty point.
- System performance at minimum and maximum system flow rate.
- Confirm heat transfer capacity of the heat exchangers.
- Confirm heat rejection rate of the cooling towers.
- Confirm that all control valves are operated within the valve's control range.
- 1 month system reliability run;

Confirm temperature parameters with at least one Unit working and with varies ambient temp (at least 5 measurements). All instruments used must be calibrated and certified.

Compile PTFD which is a P&ID marked with pressures and temperatures in the testing points.

8. OUTPUTS

The level of detail increases as the design progresses though the different design stages. The table below specifies the output at the different major design milestones. It is important to review the list and adapt it to the specific project/modification. A summary of the requirements for each of the output are provided in the subsections following the table.

Table 13 Outputs requirements in various design stages

	Concept Design	Basic Design	Process Design Freeze	Arrangement design freeze[2]	Mech. design Freeze	Integrated design
Concept Design Report	X					
Basic design report		X				
Process Design Report			X			
Mechanical detail design report					X	

	Concept Design	Basic Design	Process Design Freeze	Arrangement design freeze[2]	Mech. design Freeze	Integrated design
Overview diagrams[4]	X	X				
Process flow diagrams		X[1]	X[3]			
P&ID's		X[1]	X			
Control Philosophy			X			
Equipment lists/schedules[4]		X[5]	X		X	
Equipment specifications					X	
OEM Equipment Data sheets					X	
3D model		X	X	X	X	X
Conceptual plant layout drawings	X					
Basic Plant Layout drawings		X				
Plant Layout Drawings			X[6]	X		
Pipe and cable routing drawings		X				
Servitude defining drawings				X		
Arrangement drawings				X	X	
Piping Isometric drawings					X	
Detail drawings					X	
FMECA study		X				
HAZOP study[4]			X			X
RAM Report/Analyses			X			

Notes:

1. As is document required for projects involving modifications to existing plant;
2. The outputs listed under Arrangement Design Freeze are only the water system specific requirements and is not a complete list.
3. These outputs can be incorporated into the basic design or into the process design depending on the project;
4. The level of detail will be different depending on the design milestone;
5. Major equipment and long lead time items only.
6. Containing enough information to complete the P&ID.

8.1 CONCEPT DESIGN REPORT

The Concept design report consolidates all the inputs and outputs from the concept design stage. The report template is given in reference [69]

For cooling water systems it is important to address the following specific items.

- System description, a high level statement of the business need, aligned to the organisational strategy, with a focus on the high level processes, linking it to the business objectives and the process objective.
- The water sources;
- The users with approximate heat loads
- Operating concept (e.g. open cooling system, closed cooling system).

8.2 BASIC DESIGN REPORT

The basic design report consolidates all the inputs and outputs from the basic design stage. The report template is given in reference [70]

For cooling water systems it is important to address the following specific items.

- Design Codes to be used.
- Applicable standards
- Applicable Specifications and drawings
- Equipment requirements: The equipment requirements provide basic requirements for the selection of equipment. The detail within the schedule is dependent on the project strategy being used. Refer to Appendix B for typical equipment requirements.
- List of documents available for the existing design across all disciplines
- List of all documents that needs to cancelled and/or updated for the new design across all disciplines

8.3 PROCESS DESIGN REPORT

The Process design report consolidates all the inputs outputs from the process design stage.

For cooling water systems it is important to address the following specific items.

- Provide enough information to allow the different disciplines/design authorities to start with their detail design.
- Design parameters (Heat load, Design Flow, Pressure, Temperature etc.)
- Hydraulic analysis in enough detail to finalise the PFD and P&ID. See the Hydraulic analyses guide [54]. This is done with computerised software. The analyses should use the input information generated above. Copies of the node diagrams input and output data (including pump curves) will be included in the report.
- System resistance calculation for pipework and NPSH available for pumps
- Mass and energy balance calculations,

The Hydraulic analysis can be documented in a separate report.

8.4 MECHANICAL DETAIL DESIGN REPORT

The report template is given in reference [71]

Detail design of the following is completed in sufficient detail for procurement and manufacture:

- Cooling towers
- Supports

- Pipe racks
- Plinths for pumps, equipment, racks, supports and
- Thrust Blocks
- Hangers
- Tanks
- Valve chambers
- Arrangement and layout drawings
- Specification/s for equipment

Detail design calculations must be included. Specialised calculations like pipe stress analysis can be documented in a separate document.

8.5 OVERVIEW DIAGRAMS

Diagram providing a comprehensive view of the system with a low degree of detail.t

Also see IEC 61355 - Collection of standardized and established document kinds No. D00200

Overview diagrams of the existing plant must be created if it does not exist

8.6 PROCESS FLOW DIAGRAMS

The PFD represents a process or a process plant with the aid of graphical symbols interconnected by flow lines. The graphical symbols represent equipment and the lines represent mass and energy flows or energy carriers.

As a starting principle of specifying what a PFD shall contain, it should be stated that each PFD shall show all the major pieces of equipment, the main interconnecting piping and the key instrument control loops used in a process. The mature PFD shall also provide process condition information, process stream compositions as well as information pertaining to key utility streams either directly on the PFD or in an accompanying table [47].

If this is not available for an existing plant an as is PFD will be developed by the designer.

8.7 P&ID'S

The piping and instrument diagram (P&ID) is based on the process flow diagram and represents the technical realisation of a process by means of graphical symbols for equipment and piping together with process measurement and control elements [48].

If this is not available for an existing plant, an As-Is P&ID will be developed by the designer.

8.8 CONTROL PHILOSOPHY

The purpose of this Control Philosophy is to communicate clearly to designers and users of the processes how these processes will be controlled and what will be done to monitor the effectiveness of these processes. This process starts with the development of a plant operating concept at the start of the concept design.

The document is providing information about the behaviour of the control system in operation. The document describes in words and tables the operation of the plant as intended by the designer. This document conveys the designer's intent to the C&I engineer to design his system. Sometimes the document is referred to as a control narrative or operating control description [71]. The following should be considers when developing a control philosophy:

- System overview
- System states and modes
- Sequencing for start-up and shutdown
- Process measurements (including response characteristics and accuracies)
- Operator information display
- Equipment interlocking/logic diagram
- Process control and trip set-points
- Alarm requirements and responses
- Operator manual control actions
- Automation system responses
- Data capturing
- Equipment protection
- Control simulation
- Control verification

8.9 EQUIPMENT LISTS/SCHEDULES

The application of Plant Coding is in reference [51]. The coded P&ID is an important reference for all the lists to identify the equipment. The equipment is identified according to the applicable Eskom coding system and together with the P&ID are important conveyors of information to other disciplines.

Plant coding, the cornerstone of all configuration management and other management information systems is of utmost importance and the standardized application thereof cannot be overemphasized.

The KKS plant coding system has been adopted by Eskom and all Power Plants subsequent to Matimba will be coded with KKS (Corporate directive EVD 1085). Other coding standards are used on older stations and the Designer shall establish which system is in use.

Configuration Management

- Label list for equipment

C&I

- Control & Instrumentation Instrument Schedule Template [78].
- Control & Instrumentation Drive & Actuator Schedule Template [79]
- Virtual signal list [80]
- Panel interface list [81]

Electrical

- 240-56227927 Electrical Load List Template [74]

Mechanical

- Mechanical Equipment list template [73] serves as examples to the creation of the mechanical equipment lists

8.10 EQUIPMENT SPECIFICATION

Equipment specifications provide more detail than the Equipment lists. The equipment specifications provide enough information for an equipment supplier to supply the correct equipment. This includes critical dimensions, equipment standards and all the information which the equipment standard requires the purchaser to supply.

8.11 OEM EQUIPMENT DATA SHEETS

Data sheets are required from the OEM. These data sheets reflect the main characteristics for components including the model number.

8.12 3D MODEL

A representation of the plant in three dimensions, using a software package specially developed for the purpose.

8.13 CONCEPTUAL PLANT LAYOUT DRAWINGS

Indicate with blocks and lines the position of the, to be designed or upgraded plant. Existing structures and interfacing systems need to be indicated where applicable.

8.14 BASIC PLANT LAYOUT DRAWINGS

Drawing showing the location of sites, structures, buildings, spaces, elements, assemblies or components.

8.15 PLANT LAYOUT DRAWINGS

Drawing showing the designed plant location including structures, buildings, spaces, elements, assemblies or components.

8.16 PIPE AND CABLE ROUTING DRAWINGS

Arrangement drawing on which the location of pipe routes, road crossings, cable and pipe tunnels, trays, ducts, trunking systems, pipe racks etc. are presented

8.17 SERVITUDE DEFINING DRAWINGS

These drawings provide information regarding geographical areas reserved for specific equipment/plant and operating / maintenance access.

8.18 ARRANGEMENT DRAWINGS

Drawing showing the relative or absolute location of objects

Presentation mainly using the drawing form by showing, usually to scale, the objects and their relative position to each other.

These drawings include plans, sections, cuts, sketches and views.

This is a document providing information about shape, dimensions, placing and fixing of equipment, necessary for its proper installation.

8.19 PIPING ISOMETRIC DRAWINGS

Pictorial representation of a piping assembly, usually in isometric axonometric or perspective representation, in which components are drawn to the same scale and correctly oriented relative to each other, but are separated from each other in their correct sequence.

This is drawings which provide all necessary information for manufacture and installation of the pipe spools.

8.20 DETAIL DRAWINGS

Drawing depicting a single component and which includes all the information required for the definition of the component for manufacture.

This can be a tank or vessel drawing for manufacture, ladders and platforms etc.

8.21 FMECA STUDY

Failure Mode and Effects Analysis (FMEA) is a bottom-up analysis of a product or system to identify potential failure modes, failure causes and subsequent failure effects on system performance. FMECA (Failure Mode, Effects and Criticality Analysis) is an extension of FMEA in order to include a means of probability of failure occurrence to provide failure criticality.

FMEA is described in more detail in a separate guideline, Failure Mode and Effects Analysis Guideline, Eskom document number 240-49230046.

8.22 HAZOP STUDY

Hazard and Operability (HAZOP) analysis is a detailed hazard and operability problem identification process, carried out by a multi-disciplinary team under the guidance of an analysis leader. HAZOP deals with the identification of potential deviations from the design intent, examination of their possible causes and assessment of their consequences.

8.23 RAM REPORT/ANALYSES

System RAM (Reliability, Availability and Maintainability) Analysis refers to system evaluation in terms of reliability, availability, maintainability, life-cycle costs, throughput, etc. It includes modelling of the system using reliability block diagrams, model verification and assigning of reliability and maintainability (i.e. uptime and downtime) data to individual blocks. Reliability block diagrams show the relationship between subsystems in terms of success paths (i.e. series, parallel and other complex configurations). System RAM Analysis is typically performed using Monte Carlo simulation where a deterministic model is repeatedly evaluated [20].

In simple terms, RAM requirements are considered the upper level overarching requirements that are specified at the overall system level. It is often necessary to decompose these upper level requirements into lower level design-related quantitative requirements such as Mean Time Between Failure/Critical Failure (MTBF or MTBCF) and Mean Time To Repair (MTTR). These lower level requirements are specified at the system level; however, they can be allocated to subsystems and assemblies. The most common allocation is made to the Line Replaceable Unit (LRU), which is the unit that has lowest level of repair at the field (often called organic) level of maintenance.

Reliability Engineering refers to the Engineering discipline which addresses reliability and maintainability of a product or system during its total life-cycle. Reliability Engineering Analysis refers to the different analyses to be used for specification, allocation, designing-for, evaluation and/or measurement of reliability and maintainability of a product or system. These analyses are primarily applicable during system design but can also be used during operations and maintenance.

Reliability, Availability and Maintainability (RAM) specification refers to the specification of, primarily, quantitative reliability, availability and maintainability parameters. This activity should be performed as part of requirements analysis and, as such, be performed early during product or system development. It should include aspects such as RAM metrics, failure definitions, failure distributions, user profiles, environmental profiles, etc.

9. AUTHORISATION

This document has been seen and accepted by:

Name & Surname	Designation
[redacted]	

10. REVISIONS

Date	Rev.	Compiler	Remarks
[redacted]			Draft Document
			Draft Document for Comments Review
			Approval by LPS Study Committee
			Final Document for Authorisation and Publication

11. DEVELOPMENT TEAM

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

- [redacted]
-
-

12. ACKNOWLEDGEMENTS

- Members of the water systems care group

Appendix A: HEAT BALANCE AND HYDRAULIC CALCULATIONS

The following tables contain useful information to be used when performing hydraulic and heat balance calculations

Table 14: Common formulas

Formula	Comment
Effectiveness-NTU method [67]	Heat transfer in a heat exchanger
Bernoulli equation	Fundamental principle of fluid flow
Reynolds number	Dimensionless number used to determine if pipe flow are laminar or turbulent
Darcy-Weisbach	Friction Head loss
Swamee-Jain	Frictions factor
Henry's law	Solubility of gasses in a liquid

Table 15: Water Properties at 20 °C to be used in calculations

Item	Property	Comment
Density	998 kg/m^3	
Viscosity	1.01 10^{-3} kg/m s	
Vapour pressure	2.198 kPa	
Specific heat capacity	4.18 kJ/kgK	
Evaporation rate	2257 kJ/kgK	

Table 16: Pipe roughness in mm for use in flow calculations

Pipe material	New (mm)	Deteriorated (mm)	Comment
Drawn non-ferrous metallic and non-metallic smooth-walled pipes	0.003	0.060	From SANS 10252-1
Fibre cement	0.030	1.000	From SANS 10252-1
Galvanized mild steel	0.060	0.300	From SANS 10252-1
HDPE	0.007	0.007	
MPVC	0.0015	0.002	
Lined piping i.e. painted	0.025	0.025	
Stainless Steel	0.015	0.045	

Table 17: Head Loss Coefficient (K factor)

Item	K	Comment
Globe valve (Fully Open)	4	
Gate valve (Fully open)	0.3	

Item	**K**	**Comment**
Butterfly valve (Fully Open)	0.7	Based on Miller Type A
Ball valve (Fully Open)	0.1	
Non return/check valve swing, 90 degree seat	1.9	
90° Elbow smooth long radius	0.2	
90° Elbow smooth short radius	0.3	
90° Elbow Mitre	0.8	
Pipe Exit	1	
Pipe entrance - Sharp	0.5	

During the concept design the estimated pipe length can be multiplied by 1.25 if the number of fittings is not known.

Appendix B: EQUIPMENT REQUIREMENT SCHEDULES

Water Type	Closed cooling systems with potable water make-up	Design Pressure	0 - 1000kPa
		Design Temperature	4 - 50 °C

Item	**Size Range**	**Description**
Head Tank		
Pump	0 - 125 l/s	Single stage end suction
	100 - 500 l/s	Horizontal split casing
Isolation valve	DN 50	Hand Wheel Operated Gate Valve Female Threaded to ISO7-1/SANS 1109
	DN 80 to DN 150	Lever Operated Butterfly Valve (Lockable) Wafer Type to suit SANS1123
	>DN 200	Hand Wheel + Gearbox Operated Butterfly Valves (Lockable) Wafer Type to suit SANS1123
On Off Control valve	All Sizes	Selection based on specific requirements
Flow control valve	All Sizes	Selection based on specific requirements CV value)
Pressure regulating/Sustaining valve	25 - 600 NB	Selection based on specific requirements
Non-Return valve	DN 100 to DN 250	Dual Plate Spring Loaded Check Valves Flanged or wafer type
Drain valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Vent valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Automatic Air release valve	DN 25	Automatic Air Release / Vacuum Breaker Valve (Large Orifice) AWWA C512 - PN10 Threaded to ISO7-1/SANS 1109
PI/PIT Isolation valve	DN 15	Lever Operated Ball Valve Female Threaded to ISO7-1/SANS 1109
Flowmeter	All Sizes	Electro-magnetic
Strainer	All Sizes	Y-type and mesh size
Piping above ground	DN 15 to DN 50	SANS 62, Threaded to ISO 7-1
	DN 65 to DN 150	SANS 62, Flanged to SANS 1123
	> DN 150	SANS 719, Flanged to SANS 1123
Fittings, above ground	DN 15 to DN 50	Threaded
	> DN 50	Flanged
Flanges	All sizes	SANS 1123, 1000/3 FF

Item	**Size Range**	**Description**
Flanges, Blank	All sizes	SANS 1123, 1000/8 FF
Gaskets	All sizes	No asbestos containing materials
Flange bolting	All Sizes	Hot dipped galvanised SANS 1700, Bolts and nuts

Water Type	Closed cooling systems with demineralised water make up	Design Pressure	0 - 1000kPa
		Design Temperature	4 - 50 °C

Item	**Size Range**	**Description**
Head Tank	ALL sizes	Stainless steel
Pump	0 - 125 l/s	Single stage end suction
	100 - 500 l/s	Horizontal split casing
Isolation valve	DN 50	Hand Wheel Operated Gate Valve Female Threaded to ISO7-1/SANS 1109
	DN 80 to DN 150	Lever Operated Butterfly Valve (Lockable) Wafer Type to suit SANS1123
	>DN 200	Hand Wheel + Gearbox Operated Butterfly Valves (Lockable) Wafer Type to suit SANS1123
On Off Control valve	All Sizes	Selection based on specific requirements
Throttling valve	All Sizes	Selection based on specific requirements CV value)
Pressure regulating/Sustaining valve	All Sizes	Selection based on specific requirements
Non-Return valve	All Sizes	Dual Plate Spring Loaded Check Valves Flanged or wafer type
Drain valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Vent valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Automatic Air release valve	DN 25	Automatic Air Release / Vacuum Breaker Valve (Large Orifice) Threaded to ISO7-1/SANS 1109
Pressure release valve	DN 20	Selection based on specific requirements
PI/PIT Isolation valve	DN 15	Lever Operated Ball Valve Female Threaded to ISO7-1/SANS 1109
Flowmeter	All sizes	Ultrasonic flowmeter
Strainer		Y-type and mesh size
Piping above ground	DN 15 to DN 50	SANS 62, Threaded to ISO 7-1
	DN 65 to DN 150	SANS 62, Flanged to SANS 1123
	> DN 200	SANS 719, Flanged to SANS 1123
Fittings, above ground	DN 15 to DN 50	Threaded
	> DN 50	Flanged
Flanges	All sizes	SANS 1123, 1000/3 FF
Flanges, Blank	All sizes	SANS 1123, 1000/8 FF

Item	Size Range	Description
Gaskets	All sizes	No asbestos containing materials
Flange bolting	All Sizes	SANS 1700, Bolts and nuts

Water Type	Open evaporative cooling systems with potable and raw water make-up	Design Pressure	0 - 1000kPa
		Design Temperature	4 - 50 °C

Item	**Size Range**	**Description**
Head Tank		
Pump	0 - 125 l/s	Single stage end suction
	100 - 500 l/s	Horizontal split casing
Isolation valve	DN 50	Hand Wheel Operated Gate Valve Female Threaded to ISO7-1/SANS 1109
	DN 80 to DN 150	Lever Operated Butterfly Valve (Lockable) Wafer Type to suit SANS1123
	>DN 200	Hand Wheel + Gearbox Operated Butterfly Valves (Lockable) Wafer Type to suit SANS1123
On Off Control valve	All Sizes	Selection based on specific requirements
Flow control valve	All Sizes	Selection based on specific requirements CV value)
Pressure regulating/Sustaining valve	25 - 600 NB	Selection based on specific requirements
Non-Return valve	DN 100 to DN 250	Dual Plate Spring Loaded Check Valves Flanged or wafer type
Drain valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Vent valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Automatic Air release valve	DN 25	Automatic Air Release / Vacuum Breaker Valve (Large Orifice) AWWA C512 - PN10 Threaded to ISO7-1/SANS 1109
PI/PIT Isolation valve	DN 15	Lever Operated Ball Valve Female Threaded to ISO7-1/SANS 1109
Flowmeter	All Sizes	Electro-magnetic
Strainer	All Sizes	Selection based on specific requirements
Piping above ground	DN 15 to DN 50	SANS 62, Threaded to ISO 7-1
	DN 65 to DN 150	SANS 62, Flanged to SANS 1123
	> DN 150	SANS 719, Flanged to SANS 1123
Fittings, above ground	DN 15 to DN 50	Threaded
	> DN 50	Flanged
Flanges	All sizes	SANS 1123, 1000/3 FF
Flanges, Blank	All sizes	SANS 1123, 1000/8 FF

Item	Size Range	Description
Gaskets	All sizes	No asbestos containing materials
Flange bolting	All Sizes	Hot dipped galvanised SANS 1700, Bolts and nuts

Water Type	Open evaporative cooling systems with demineralised water make-up	Design Pressure	0 - 1000kPa
		Design Temperature	4 - 50 °C

Item	**Size Range**	**Description**
Pump	0 - 125 l/s	Single stage end suction
	100 - 500 l/s	Horizontal split casing
Isolation valve	DN 50	Hand Wheel Operated Gate Valve Female Threaded to ISO7-1/SANS 1109
	DN 80 to DN 150	Lever Operated Butterfly Valve (Lockable) Wafer Type to suit SANS1123
	>DN 200	Hand Wheel + Gearbox Operated Butterfly Valves (Lockable) Wafer Type to suit SANS1123
On Off Control valve	All Sizes	Selection based on specific requirements
Throttling valve	All Sizes	Selection based on specific requirements CV value)
Pressure regulating/Sustaining valve	All Sizes	Selection based on specific requirements
Non-Return valve	All Sizes	Dual Plate Spring Loaded Check Valves Flanged or wafer type
Drain valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Vent valve	DN 25	Hand Wheel Operated Gate Valves Female Threaded to ISO7-1/SANS 1109
Automatic Air release valve	DN 25	Automatic Air Release / Vacuum Breaker Valve (Large Orifice) Threaded to ISO7-1/SANS 1109
Pressure release valve	DN 20	Selection based on specific requirements
PI/PIT Isolation valve	DN 15	Lever Operated Ball Valve Female Threaded to ISO7-1/SANS 1109
Flowmeter	All sizes	Ultrasonic flowmeter
Strainer	All size	Selection based on specific requirements
Piping above ground	DN 15 to DN 50	SANS 62, Threaded to ISO 7-1
	DN 65 to DN 150	SANS 62, Flanged to SANS 1123
	> DN 200	SANS 719, Flanged to SANS 1123
Fittings, above ground	DN 15 to DN 50	Threaded
	> DN 50	Flanged
Flanges	All sizes	SANS 1123, 1000/3 FF
Flanges, Blank	All sizes	SANS 1123, 1000/8 FF
Gaskets	All sizes	No asbestos containing materials

Item	Size Range	Description
Flange bolting	All Sizes	SANS 1700, Bolts and nuts

Appendix C: TYPICAL PLANT LIFE

Plant/Component	Type	Main Failure Mechanism	Lifespan (Years)	Refurbish / Replace	Notes
Pumps	Centrifugal Submersible	Internal Corrosion/Efficiency Loss/Obsolescence	15	Replace	Refurbish every 5 Years
Pumps	Centrifugal Horizontal Split Casing	Internal Corrosion/Efficiency Loss/Obsolescence	30	Replace	Refurbish every 5 Years, Replace Casing after 15 Years
Pumps	Centrifugal Vertical Split Casing	Internal Corrosion/Efficiency Loss/Obsolescence	30	Replace	Refurbish every 5 Years, Replace Casing after 15 Years
Pumps	Positive Displacement - Screw	Wear Internal Corrosion/Efficiency Loss/Obsolescence	15	Replace	Refurbish every 5 Years
Pumps	Positive Displacement - Piston	Wear Internal Corrosion/Efficiency Loss/Obsolescence	15	Replace	Refurbish every 5 Years
Pumps	Positive Displacement - Diaphragm	Wear Internal Corrosion/Efficiency Loss/Obsolescence	15	Replace	Refurbish every 5 Years
Valves	Butterfly - Zero Offset Stainless Disc and Non-Replaceable Liner	Wear	10	Replace	
Valves	Butterfly - Zero Offset Stainless Disc and Replaceable Liner	Wear	20	Replace	Replace Liner every 10 years
Valves	Butterfly - Double Offset, Epoxy Coated, Stainless Seats/Rings and Replaceable Seals	Wear/Corrosion	30	Replace	Replace seals every 15 years
Valves	Butterfly - Triple Offset, Epoxy Coated, Stainless Seats/Rings and Replaceable Seals	Wear/Corrosion	30	Replace	Replace seals every 15 years
Valves	Gate	Wear/Corrosion	10	Replace	
Valves	Ball - Stainless Steel (Replaceable Seals)	Wear	15	Refurbish	

Valves	Plug	Wear	10	Replace	Refurbish (Replace seals, machine faces) every 5 years
Valves	Diaphragm	Wear/Corrosion	30	Replace	Replace diaphragm every 15 years
Gearbox	Butterfly Valve	Wear	30	Replace	Refurbish/Replace in Conjunction with Valve
Tanks & Vessels	Concrete		60		As per Civil Engineering Replacement/Refurbishment Guides
Tanks & Vessels	Fibre Glass		60		Inspect for Wear/Damage every 5 years
Tanks & Vessels	Galvanised & Rubber Lined		60		Inspect for Wear/Damage every 5 years
Tanks & Vessels	Stainless Steel		60		Inspect for Wear/Damage every 10 years
Pipelines	Hot Dip Galv Carbon Steel (Externally Wrapped when Buried)	Internal Corrosion	30	Replace	
Pipelines	Epoxy Coated Carbon Steel (Wrapped when Buried)	Internal Corrosion	20	Replace Coating	
Motors	All				As per Electrical Engineering Replacement Guide
Controls	All				As per C&I Engineering Replacement Guidance
Instrumentation	All				As per C&I Engineering Replacement Guidance
Actuators	All				As per C&I Engineering Replacement Guidance
Protections	All				