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Document Title	SYSTEM DESIGN DESCRIPTION: SMELTER EMERGENCY COOLING WATER COOLECTION SYSTEM
Number	NLM-DP-00003
Date	24 January 2025
Revision	2.0

APPROVAL & DISTRIBUTION

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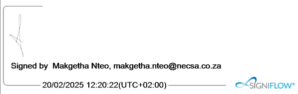
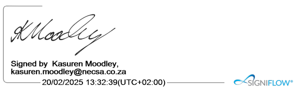
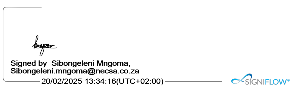
Prepared	Makgetha Nteo Mechanical Engineer Engineering Service		
Reviewed	Kasuren Moodley Chief Process Engineer Engineering Services		
Approved	Sibongeleni Mngoma Chief Mechanical Engineer Engineering Services		
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1. PURPOSE

This document describes the system for the collection and storage of emergency cooling water for the smelter facility at Area 26.

2. SCOPE

This document covers the design and description of the emergency water collection system for the smelter facility at Area 26. The following aspects are covered:

- Design of the pipeline subsystem from the smelter furnace coils to the storage tank.
- Design of the storage tank and bund area. Sizing of the tank was reported in NLM-REP-22/042 [1] and forms the basis for the bund sizing and tank dimensions.

This document details the boundaries and interfaces of the emergency water collection system. As part of the design, the P&ID for the smelter system [2] was reviewed and recommendations have been provided. The last section of this report details information that is outstanding that must be obtained prior to implementation of the system described herein.

3. REFERENCES

[1] NECSA, "NLM-REP-22/042 Smelter Emergency Cooling Water Hold-up Tank Sizing," 2022.

[2] NECSA, "NND-V-26-Y-PROPID-0002 Furnace and Emergency Water Sytem PID Rev 0.1".

[3] NECSA, "H0520-597-01: Water Interconnect Cooling PID".

[4] Pelchem, "PCM-MEC-SPE-15056: Pipeline Material Specification, Carbon Steel Class 150".

[5] NECSA, "NNDD-V-26-Y-PROPID-0006 Emergency Cooling Water Collection PID".

[6] NECSA, "NLM-SAR-08/001: Smelter Safety Assessment Report".

[7] Pillar Industries, "PP1242-2 MK15 Power Supply Instruction Manual".

[8] ASME, "Process Piping: ASME Code for Pressure Piping, B31," 2012.

[9] NECSA, "NED-SHEQ-PRO-11009: NED Procedure for Numbering of Drawings and Hardware Rev 01".

[10] NECSA, "NNDD-V-26-C-BUNDE-0002 Emergency Cooling Water Bund".

[11] "SANS 347:2019 SOUTH AFRICAN NATIONAL STANDARD Categorization and conformity assessment criteria for all pressure equipment".

[12] NECSA, "7371-26-01-E20901 V-26 Single Line Diagram for Board V-26-VL001-EBE001".

[13] Burkert, "2/2-way-solenoid valve; servo assisted," [Online]. Available: https://www.burkert.co.za/en/products/solenoid-valves/water-solenoid-valves/221948. [Accessed 01 March 2023].

[14] Process Industry Practices: Piping, "PIP PNCM0002 Piping Material Specifications Line Class Index," 2006.

4. LIST OF ABBREVIATIONS

AMB	Ambient
AODD	Air Operated Double Diaphragm
ATM	Atmosphere
BSP	British Standard Pipe
CS	Carbon steel
LEMS	Liquid Effluent Management Services
MOC	Material of Construction
NECSA	The South African Nuclear Energy Corporation SOC Ltd.
NLM	Nuclear Liabilities Management (division of NECSA)
NPT	National Pipe Thread (ASME standard B1.20.1)
OEM	Original Equipment Manufacturer
P&ID	Piping and Instrumentation Diagram
PIP	Process Industry Practices
PP	Polypropylene
PVC	Polyvinylchloride
SANS	South African National Standards
SSC	Systems, Structures and Components
TBC	To be confirmed
TBD	To be determined

5. LIST OF SYMBOLS

(g)	gauge
°C	Degree Celsius
µm	micrometer
kPa	Kilopascal
m	Meter
m^3	Cubic meter
min	Minute(s)
mm	Millimeter
Nm^3	Normal cubic meter

6. GENERAL OVERVIEW

The South African Nuclear Energy Corporation SOC Ltd (NECSA) has built an induction furnace smelter for the purpose of reducing the volume of uranium contaminated scrap metal originating from various plants and processes. The scrap metal is melted in the presence of flux material that ensures the uranium is concentrated into the slag layer. The slag layer is removed by ladle and the uranium-free metal melt is cast into ingots for re-sale or safe disposal. The type of material to be processed are ferrous and non-ferrous scrap metals stored on the Pelindaba site. The smelter has a primary cooling water system that cools the electric panel and the copper induction coils of the induction furnace.

The copper induction coils of the induction furnace are cooled with process water under normal operating conditions. When the primary furnace cooling water becomes unavailable, such as in the case of loss of power supply to the smelter facility, emergency cooling water will be used to remove the residual heat in the induction coils to prevent damage to the coils. The source of the emergency cooling water is an on-site reservoir filled with potable water from Rand Water. The emergency cooling water flows through the induction coils in a single pass; it does not circulate through the existing primary cooling water closed-loop system. The emergency water enters the system, cools the induction coils, and exits the coils to a temporary holding tank. The emergency cooling water only cools the induction coils and not the electrical panels.

The melt may contain uranium material and there exists a possibility of cross contamination of the emergency cooling water with radioactive material from the smelter. The discharged emergency cooling water, therefore, shall be stored temporarily in a tank to permit sampling and analysis for uranium material or other radioactive contamination. Upon receipt of the analytical results of the sampled water, the emergency cooling water shall be sent for further processing or disposal to Decontamination Services or Liquid Effluent Management Services (LEMS).

7. SYSTEM FUNCTIONS

The emergency cooling water system shall be used in the event of loss of the primary cooling water system. In the event that the primary cooling water system fails or is unavailable, the induction coils will not be cooled, and the water temperature will keep rising leading to expansion of the water. This may cause rupture and/or corrosion of the induction coils and/or risk of a steam explosion. Therefore, the induction coils must be cooled to a safe temperature by an emergency cooling water system.

The primary cooling water system is expected to malfunction if any of the following events were to occur [1]:

1. The differential pressure between inlet and outlet cooling water lines falls below 207 kPa (30 psi).
2. Cooling water inlet and outlet temperature rises to 46 °C and 65 °C, respectively.

3. Unavailability of the two installed cooling water system pumps (primary and backup).
4. Cooling tower malfunction.
5. Loss of electrical power supply, including backup power.

The emergency cooling water shall be used for a maximum period of 240 minutes (4 hours) to ensure the safe cooling of the copper induction coils. Operating parameters are summarised in Table 7-1. Further details are provided in NLM-REP-22/042 [1].

Table 7-1: Emergency cooling water operating parameters

Parameter	Details	Reference
Switchover	Automatic	[2]
Flowrate	50 L·min^{-1}	[3]
Delivery pressure at inlet to induction coils	>100 kPa(g)	[3]
Inlet temperature	AMB	[1]
Cooling time	4 hours	[1]
Total maximum emergency cooling water required	12 m^3	[1]

8. REQUIREMENTS AND BASES

The primary function of the emergency cooling water system is the safe cooling of the copper induction coils. This is achieved by cooling the coils for a period of 240 minutes after the furnace has been shut down [1]. Due to possible contamination of the cooling water, it is collected in a temporary storage tank. The uranium content in the water shall be analyzed prior to further processing.

8.1 DESIGN BASIS

The following parameters form the basis of the emergency cooling water system design. The OEM specified a minimum requirement for the emergency cooling water flow and delivery pressure of 50 L·min^{-1} and 100 kPa(g), respectively. Pipeline diameter is provided in the P&ID provided by the OEM [3].

Table 8-1: Input to design

No.	Description	Value	Units	Ref.	Assumption
1	Atmospheric pressure	87-88	kPa(a)	Engineering Services	N
2	Emergency water flow required	50	$L\cdot min^{-1}$	*H0520-597-01* [3]	N
3	Emergency water inlet diameter	40	mm OD	*H0520-597-01* [3]	N
4	Emergency water outlet diameter	40	mm OD	Site inspection	N
5	Emergency cooling water delivery pressure	>100	kPa(g)	Assumption	Y

8.2 ASSUMPTIONS

The emergency cooling water system has been designed with the following assumptions:

1. The emergency cooling water feed has:
    a. Sufficient line pressure to pass through the cooling coils as required by the furnace OEM [3] for the entire duration of the cooling operation.
    b. Sufficient flow to achieve the required cooling as required by the furnace OEM [3] for the entire duration of the cooling operation.
    c. Sufficient capacity to allow cooling for 4 hours [1].
2. The operator is available during the event that causes a loss of primary cooling water.

The radiative heating caused by the thermal mass of the furnace should it not be tipped has not been accounted for in calculating emergency cooling water requirements.

8.3 SAFETY MARGINS

Sufficient safety margins were employed to provide reasonable assurance that no significant event will occur when the operating conditions or limits are exceeded.

8.3.1 PRESSURE

Carbon steel pipe with rating of class 125 was selected as the MOC for the emergency cooling water system. The selected line class is rated to 1035 kPa(g) up to 38 °C; and 930 kPa(g) up to 93 °C [4]. The collection tank is operated at ambient conditions.

8.3.2 TEMPERATURE

The selected carbon steel pipe is rated up 93 °C. Instantaneous temperature is not expected to exceed 94 °C [1].

8.3.3 LIQUID LEVELS

Given the possibility of radioactivity in-, and the amount of collected emergency cooling water, the collection tank shall not be filled beyond 90 % of its capacity. Further, the tank shall have a free board vapour space of at least 300 mm. The bund is designed to hold 110% of the tank volume.

9. SYSTEM DESCRIPTION

The emergency cooling water system is separated into 3 subsystems:

- Emergency cooling water feed and storage
- Furnace induction coil heat transfer
- Emergency cooling water collection and storage

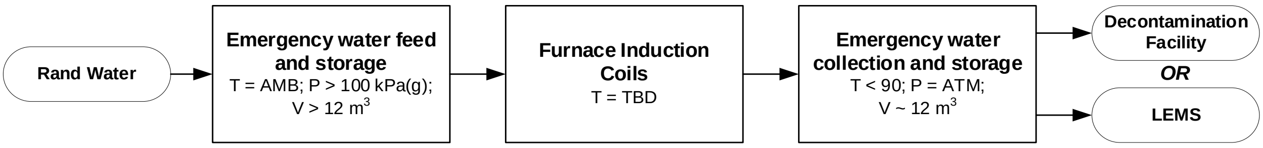

Figure 9-1: High level overview of the smelter facility emergency cooling water system

The design and construction of the emergency cooling water feed subsystem has been completed. NNDD-V-26-Y-PROPID-0002 [2] details the piping and instrumentation of the feed subsystem.

The heat transfer subsystem (furnace induction coils) forms part of the primary cooling water system. When emergency cooling water is used, the feed to this system is automatically switched over from primary cooling water to the emergency cooling water.

The third subsystem, the emergency cooling water collection and storage forms the focus of this report and will be discussed in the sections that follow. The piping and instrumentation associated with the subsystem is shown in NNDD-V-26-Y-PROPID-0006 [4]. The subsystem has been allocated the area code 21

The smelter Safety Assessment Report [5, p. 69] lists the flow indicator (to be installed, not indicated on NNDD-V-26-Y-PROPID-0002 [2]) on the primary cooling water system as a System, Structure or Component (SSC) with safety significance. The furnace operation is ceased if the primary cooling water temperature is too high or if the cooling water pressure is too high/low [6, pp. Installation Instructions, Section D]. The interlocks provided for flow control through the furnace, together with their associated instrumentation, are not indicated on the currently available P&ID [2] but are indicated as part of the furnace OEM package [6, pp. Installation Instructions, Section E]. Valve V0159 BRK038 does, however, form part of the interlock system for switchover from the primary cooling water to the emergency cooling water.

The Safety Assessment Report [5] does not make explicit provision for the instrumentation and hardware in the emergency cooling water system with respect to SSC safety classification. The report does indicate that all existing SSC in the smelter facility are classified as SC-3 [5, p. 34]. This classification was therefore extended to the SSC in the emergency cooling water system.

9.1 PIPE SYSTEM

The piping from the furnace cooling system shall be designed and constructed in accordance with applicable codes (ASME B31.3-2012 [4]). The naming convention of NECSA's Engineering Services [7] has been followed in developing the P&ID for the system. The tie-in (interface) point between the new emergency cooling water collection system and the existing smelter facility is a 40 mm carbon steel pipe with NPT straight thread, at the point where the pipe exits the Area 26 building on its west side. The 40 mm specification will be continued in the new pipeline design. The same MOC was selected for the pipe system, in accordance with existing pipes on the system [2]. A schematic of the pipe system is shown in Figure 9-2 [8]. To the east of the pipeline is the Area 26 main building. To the south of the pipeline is the stack building.

The pipe shall be supported by pipe racks. The pipe rack design shall be completed as part of the mechanical design.

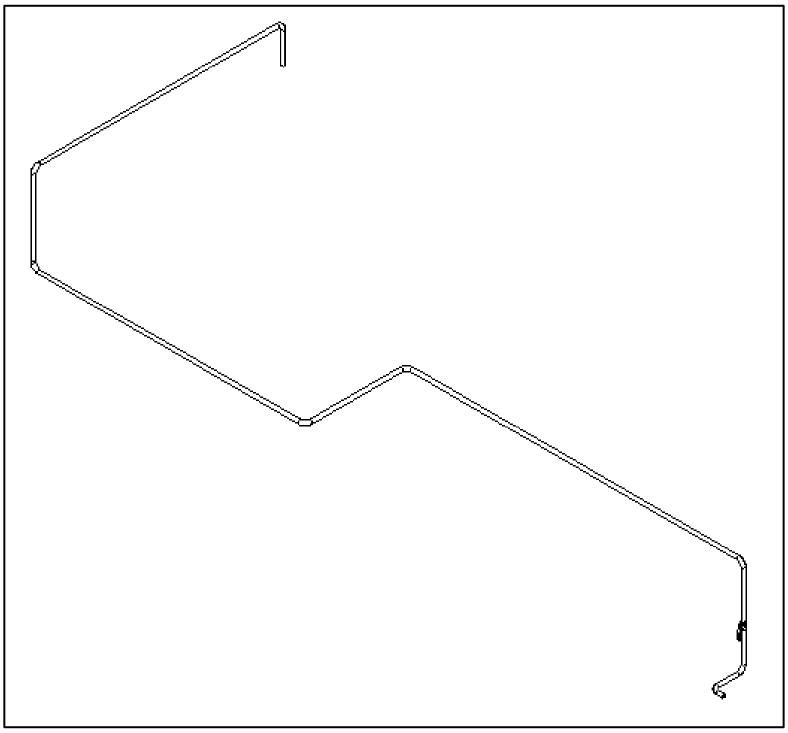

Figure 9-2: Pipeline schematic for the smelter emergency cooling water collection and storage system [8]

9.2 STORAGE TANK

The storage tank shall be located outdoors and operated under atmospheric conditions and shall thus be designed and constructed according to standard engineering practice as prescribed by SANS 347:2019 [4]. The tank shall be constructed from carbon steel. Excess water overflows out of the tank and accumulates inside the bund. The steel shall be treated to ensure rust prevention e.g., galvanizing, painting. The tank shall be placed flat on the base plinth. Parameters for the storage tank sizing are provided in NLM-REP-22/042 [1].

Table 9-1: Emergency cooling water storage tank parameters

Parameter	Value	Unit
Geometry	Round	-
MOC	Carbon steel	-
Covered	Yes	-
Diameter	2.6	m
Total height	3.26	m
Design volume[1]	15	m^3

[1] 15m^3 is selected from a standard tank size of a Jojo tank to obtain the diameter and height. The actual volume for the tank is 17.31m^3

9.3 BUND

The bund shall be constructed from reinforced concrete and lined or coated with an impermeable barrier to prevent the transport of fluid through the walls. The bund wall for this system is specified with a height of 1.12 m. The bund is specified with an outside length of 7 m and a width of 5 m; and a wall thickness of 0.2 m The dimensions also allow sufficient space between the bund walls and the tank walls to enable tank inspection and maintenance. The bund shall include a square hole (sump) for the insertion of an extraction pipe to be connected to an self-priming recirculation pump. The same pump shall be used to empty the emergency cooling water tank. The pump shall be permanently stationed in the bund area. The sump shall be covered with a galvanized carbon steel grid. The bund concrete design was completed according to SANS 10100 (2000). Steel design was completed according to SANS 10162 (2011). Loading designs were completed according to SANS 10160 (2019).

Table 9-2: Emergency cooling water bund parameters

Parameter		Unit
Geometry	Rectangular	-
MOC	Reinforced concrete	-
Length	6.6	m
Width	4.6	m
Height	1.05	m
Design volume	25	m^3

9.4 EQUIPMENT LIST

Table 9-3: Equipment list for emergency cooling water collection system

Equipment Number	Equipment Type	Description	MOC	Capacity (m^3)	Capacity ($m^3 \cdot h^{-1}$)	Duty (kW)	Width (m)	Height (m)	Length (m)	Area (m^2)
T2101	Tank	Emergency water collection tank	Carbon steel	15	-	N/A	2.5	2.7	-	-
Y2102	Bund	Emergency water collection tank bund	Reinforced concrete with lining	25.8	-	N/A	5	1.12	7	35[1]
P2103	Pump[2]	Self-priming centrifugal pump	Consideration of not causing galvanic corrosion with pipes, to be confirmed when specifying pump duty point.	-	42	N/A	0.404	0.668	0.659	0.3

[1]Bund dimensions are showing for the outside and indicate footprint; not area associated with storage capacity.

[2]A suitable alternative model may also be considered.

9.5 LINE LIST

Table 9-4: Line list for emergency cooling water collection system

Line Number	MOC	Size (mm)	Insulation	P&ID Number	Fluid	Process From	Process To
40-21-WCCP-001	CS	40	N/A	NNDD-V-26-Y-PRPPID-0006	Cooling water	Furnace induction coils cooling water	Emergency cooling water collection tank
40-21-WCCP-002	CS	40	N/A	NNDD-V-26-Y-PRPPID-0006	Cooling water	Emergency cooling water collection tank	Self-priming centrifugal pump
15-21-WCCP-003	CS	15	N/A	NNDD-V-26-Y-PRPPID-0006	Cooling water	Self-priming centrifugal pump discharge line	Pressure Indicator
40-21-WCCP-004	CS	40	N/A	NNDD-V-26-Y-PRPPID-0006	Cooling water	Self-priming centrifugal pump and mobile tanker T-joint	Mobile tanker

General notes:

1. A 40 mm pipe shall be used to drain the sump.

9.6 VALVE LIST

Table 9-5: Valve list for emergency cooling water collection system

Tag Number	Line Number	Type	Fluid	MOC	Size (mm)	P&ID Number
WC21-01 CB0-40	40-21-WCCP-001	Ball	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006
WC21-02 CZ0-40	40-21-WCCP-001	Float valve	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006
WC21-03 CB0-40	40-21-WCCP-002	Ball	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006
WC21-04 CB0-40	T-jointed to 40-21-WCCP-002	Ball	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006
WC21-05 CB0-15	15-21-WCCP-003	Ball	Cooling water	CS	15	NNDD-V-26-Y-PROPPID-0006
WC21-06 CB0-40	40-21-WCCP-004	Ball	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006
WC21-07 CQ0-40	40-21-WCCP-002	Strainer	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006
WC21-08 CC0-40	40-21-WCCP-004	Hose	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006
WC21-09 CU0-40	40-21-WCCP-002	Check valve	Cooling water	CS	40	NNDD-V-26-Y-PROPPID-0006

10. BOUNDARIES AND INTERFACES

A high-level battery limit schematic is presented in Figure 10-1.

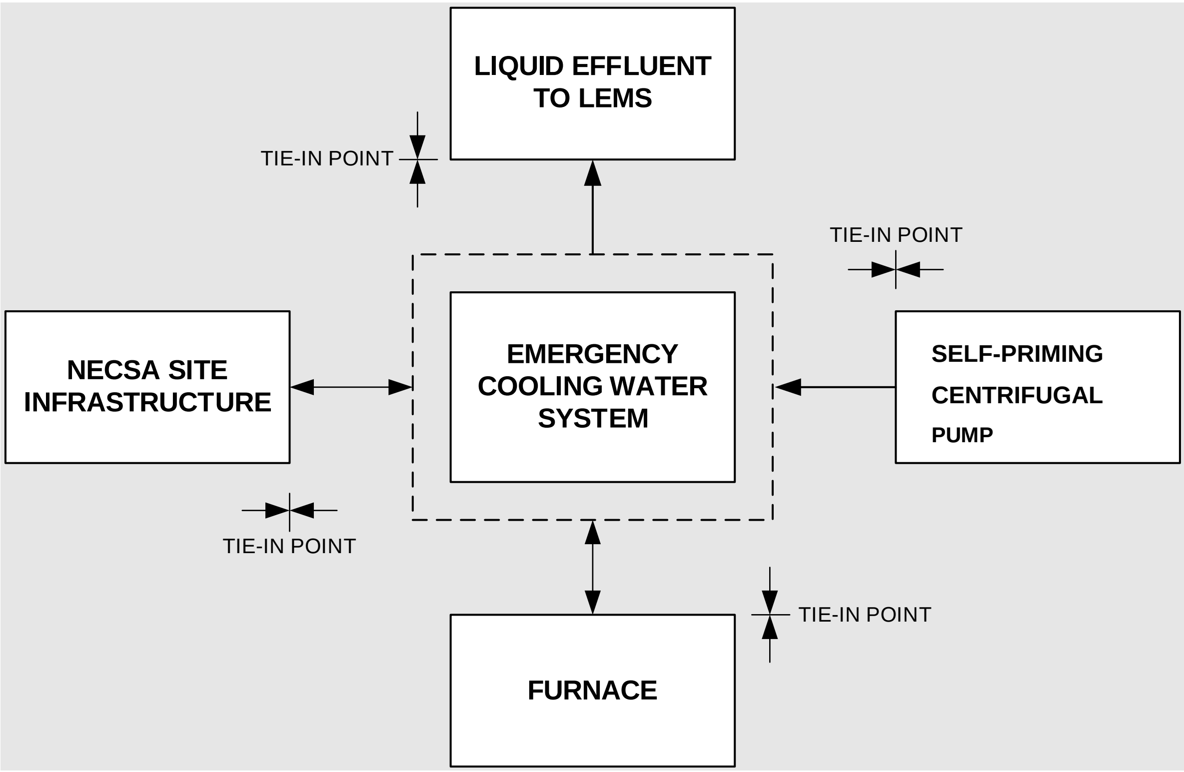

Figure 10-1: High level battery limit schedule for the smelter facility emergency cooling water system

The following tie-in points are present:

1. Self-priming centrifugal pump to produce pressure to move cooling water from tank to mobile tanker.
2. Cooling water enters the collection system through pipeline 100mm-01-CW-SS-041 as indicated in NNDD-V-26-Y-PROPID-0002 [2].
3. Collected cooling is drained from the holding tank T2101 to the mobile tanker through line 50-21-WC-CP-002 as indicated in NNDD-V-26-Y-PROPID-0006 [4].
4. Use of site infrastructure from the Area 26 facility such as exterior lighting

It is assumed that the following utilities are available or will be made available at the smelter facility:

- Emergency cooling water feed storage with a minimum capacity of 12 m^3

10.1 INTERFACE LIST

Table 10-1: Interface list for the emergency cooling water system

		Interface Conditions					Connection		
Interface Location (Line numbers)	**P&ID No.**	**Oper. T (°C)**	**Oper. P (kPa(g))**	**Design T (°C)**	**Design P (kPa(g))**	**Max Flowrate ($L \cdot min^{-1}$)**	**Size (mm)**	**Type**	**Comments**
100mm-01-CW-SS-041	NNDD-V-26-Y-PROPID-0002	AMB	>100	90	>100	50	50	BSP	Emergency cooling water inlet

11. SYSTEM LAYOUT

The emergency cooling water collection and storage system is located outside the Area 26 building, on the western side. NNDD-V-26-C-BUNDE-0002 [9] provides additional detail on the system layout.

12. SYSTEM RELIABILITY FEATURES

The emergency cooling water system is activated when there is a loss of power. As a result, the instrumentation of the system is mechanical/analogue in nature. A mechanical level switch (float valve) WB0502 CZ050 has been specified for use in the system. Upon reaching the maximum level in the tank T0501, the feed valve to T0501, WB0502 CZ050, is mechanically closed.

The AODD pump requires compressed air for operation. The pump is operated intermittently when the tank T0501 or bund Y0502 are drained. Loss in compressed air will not have a safety impact. However, it may cause a delay in draining the tank or bund.

13. SYSTEM CONTROL FEATURES

The liquid level in the storage tank is controlled automatically *via* the use of a float valve WB0502 CZ050. Liquid level in the tank is indicated by LI0501. The tank may be filled up to 90% at which point the valve closes. This amounts to 15 m^3 of water whilst still maintaining a 300 mm freeboard above the liquid level. 15 m^3 is 125% the required storage volume of 12 m^3. A high-level P&ID is presented in Figure 13-1 [4].

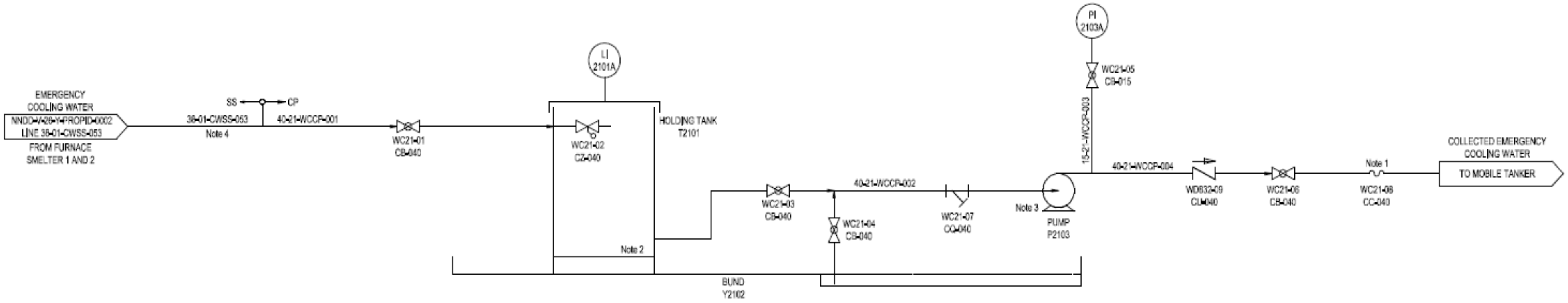

Figure 13-1: High level P&ID of the emergency cooling water system collection and storage subsystem NNDD-V-26-Y-PRPID-0006 [4]

14. OPERATION OF THE COOLING WATER SYSTEM

14.1 NORMAL OPERATION

During normal operation, the primary cooling water system is in operation. Cooling water from the closed circuit cooling tower is pumped through both furnaces and their corresponding electrical panels. Valves V0170 CG050 and V0173 CG076 remain open [2], allowing for the circulation of the cooling water through the system.

14.2 LOSS OF MAINS POWER; EMERGENCY BACKUP AVAILABLE

In the event of a loss of mains power, the primary cool water shall operate off backup power [12]. The following items are operated off backup power from board V-26-VL001-EBE0001 [12]:

- Smelter hydraulic system
- Primary cooling water system (including pumps and cooling tower fans)
- Emergency water release control panel (V0159 BRK038 and V0166 SK036 [2])

Reading 7371-26-01-E20901 [12] along with NNDD-V-26-PROPID-0002 [2], in the event of a loss of mains power, the operator shall safely end a run (the induction heating coils are not powered off backup power) and tip the furnace using the smelter hydraulic system. The system shall be brought to a safe temperature using the primary cooling water system.

14.3 LOSS OF MAINS POWER, EMERGENCY BACKUP NOT AVAILABLE

In the event of a loss in mains power and emergency backup, the emergency cooling water system shall be used to safely shut down the system. Primary cooling water is not available. Valve V0159 BRK038 and V0166 SK036 shown in NNDD-V-26-Y-PROPID-0002 [2] fail open [11], allowing the emergency cooling water to flow through the system. The operator shall close V0170 CG050 and V0173 CG076 [2] to prevent the emergency cooling water from entering the primary cooling water system.

The emergency cooling water flows through the system at 50 $L \cdot min^{-1}$ for a period of 4 hours at which point feed to holding tank T2101 [4] is automatically shut off by valve WC2102 CZ040. This stops the flow of cooling water through the system. Manual valves WC2101 CB040 AND WC2103 CB040 shall remain open and are only shut off when tank T2101 is to be isolated. Manual valve WC2104 CB040 remains closed unless the sump of the bund is being drained.

Prior to resuming normal operation, T2101 shall be drained using self-priming centrifugal pump P2103.

15. RECOMMENDATIONS

The following recommendations are made to improve the operability and safety characteristics of the cooling water circuit—both primary and emergency

- Valves V0170 CG050 and V0173 CG076 should be automated to minimize operator requirements should a power failure occur. It is recommended that solenoid valves that fail close be installed.
- A safety evaluation should be conducted to assess the risks associated with the operators being unable to tip the furnace in the event of a complete loss of power.

16. INFORMATION TO BE CONFIRMED/VERIFIED

The following is a list of parameters/details that need to be confirmed prior to moving to the next phase of the work

Area	Parameter/Details	Impact/Consequences
Emergency cooling water feed	Delivery pressure	The delivery pressure must be determined in order to ascertain if there is sufficient head in the line to overcome pressure losses in the emergency cooling water circuit.
Emergency cooling water feed	Delivery flow	The delivery flow must be confirmed to ensure that sufficient flow (as set out by the furnace OEM) is available to ensure adequate cooling.
Emergency cooling water feed	Total volume of cooling water available and guarantee of supply	Emergency cooling water supply and quantity must be guaranteed to ensure availability of the emergency cooling water system
Bund	Roofing system	Roofing system design to be completed to protect the bund system from rainwater

17. APPENDIX A: TANK DIMENSION CALCULATIONS

Table A- 1: Calculation inputs and results

Row	Parameter	Value	Unit	Notes/Reference
1	Minimum required size	12.0	m^3	[1]
2	Design size	14.4	m^3	20 % design factor
3	Geometry	Circle		
4	MOC	Carbon steel		
5	Diameter	2.6	m	
6	Height (filled)	2.83	m	
7	Height (including freeboard)	3.26	m	300 mm freeboard
8	Tank volume (excl. freeboard)	15.00	m^3	

Table A- 2: Notes to the calculation inputs and results

Row	Note
1	The minimum required tank size was calculated and reported on previously [1] and formed an input into this calculation.
2	A minimum design size of 14.4 m^3 was determined using a design factor of 1.2 or 20 %.
3	A square geometry was selected due to the high availability of pressed carbon steel plates. The plates allow for an easily customizable sized tank. Additionally, there was no pressure vessel considerations given that the vessel is operated at atmospheric conditions
4	Pressed carbon steel plates are commonplace in manufacture of waste storage tanks and this MoC was thus selected.
5&6	Reasonable dimensions were selected for the length which in turn informed the height of the tank. Available area at the facility was taken into consideration when selecting tank dimension.
8	A 300 mm freeboard was selected to ensure that any splashing/waves that that may occur at the surface of the liquid when the tank is filled will have no significant effect on the tank structure.