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1. INTRODUCTION

Arrangement Design is the placement and integration of Systems, Structures, and Components (SSC) within a site, plant, building or area to facilitate optimal functionality, operability, and cost, while ensuring adequate clearance for the construction, installation, maintenance and emergency access an egress routes summarised as the following:

- Ensuring compliance with [3] SANS10400 - The Application of the National Building Regulations.
- Ensuring a plant arrangement design that complies with the [4] Occupational Health and Safety Act, and optimises health and safety during construction and operation.
- Ensuring adequate clearance for the construction, installation, operation, and maintenance of plant, equipment and components.
- Prevent/identify/resolve interferences between plant components designed and/or procured by the design engineering disciplines and the specialty sections and produce a design that results in “zero interferences” in the field.

Projects require the use of 3-D computer modelling to perform arrangement design in order to optimise the plant layout and effectively minimise interferences. The 2-D general arrangement drawings are generated from the 3-D model.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

This guideline defines the methodologies and responsibilities for the arrangement design of a plant, buildings, structures, or areas for a project.

2.1.2 Applicability

This guideline applies to all project design work performed by Eskom.

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] 240-53113685 Design Review Procedure
[2] 240-53114026 Project Engineering Change Management Procedure

2.2.2 Informative

[3] SANS 10400 The Application of the National Building Regulations
[4] Occupational Health and Safety Act

2.3 DEFINITIONS

2.4 ABBREVIATIONS

2-D	Two-Dimensional
3-D	Three-Dimensional
CAD	Computer Aided Design
GA	General Arrangement
HVAC	Heating, ventilation and Air conditioning
LDE	Lead Discipline Engineer
PBS	Plant Breakdown Structure
PEM	Project Engineering Manager
PFD	Process Flow Diagram
PPM	Package Manager
WGS	World Geodetic System

2.5 ROLES AND RESPONSIBILITIES

The allocation of responsibilities to the appropriate disciplines should be contained in the project charter. This is different for each project depending on the type of power generation and extent of the project.

Interference checking should be performed prior to all other 3D design reviews. See **240-92723662 Multi Discipline Interference Checking Guideline**.

It is important to note that the 3D model represents the plant that is to be built; the total end product in three dimensions. It is the core of the design base. Therefore, to fully utilize this tool, all those personnel who may have an impact, and / or who will be affected by, or involved with the plant under design should and can contribute to the optimization of the design. Arrangement design and interference checking are not the only design and quality assurance activities performed on the 3D Model. [1] Design Review Procedure

3. ARRANGEMENT DESIGN GUIDELINE

3.1 ARRANGEMENT DESIGN WORKFLOW

The arrangement design guideline requires input and coordination between all disciplines and vendors through the entire project life cycle.

3.2 ARRANGEMENT DESIGN METHODS

This guideline shall be performed using the following communication methods, tools, and deliverables:

- Three Dimensional (3-D) Computer Modelling.
- Location Plan.
- Site Layout Drawing.
- Station Layout Drawing.
- General Arrangement Drawings (GA).
- Composite Detail Drawings.
- Design Data Exchange.
- Design Change Management.
- Arrangement Design Meetings

3.2.1 Three-Dimensional Computer Modelling

The Three Dimensional Computer Model is the most critical design control medium that is required for all projects. The generation of the 3D model should begin as early as possible, preferably at the beginning of the feasibility study phase, and develop as the design progresses through to construction and operation.

All the systems, structures and components shall be placed in the project's 3-D model as per the Plant Breakdown Structure (PBS).

In order to facilitate a fully integrated 3D model of the entire plant, minimum detail shall be indicated. Detail shall be sufficient to clearly define the required object; the outer envelope and external interfaces with only sufficient detail to facilitate interference checking and interfaces with the object. Internal and minor parts shall not be modelled unless specified by the project as a requirement.

It is imperative that the following be modelled as early as possible in the design:

- Terrace
- Underground services such as: sewage, clean and dirty drains, tunnels, trenches, ring mains (fire, electrical, C&I and telecommunications).
- Site perimeter and fencing, including ash dumps.
- All major interfaces with the station such as, access road/s, water supply,
- Railway link
- Station roads with clearance heights

- Placement of volumetric models (space allocation/footprint) of major systems, structures and buildings (trenches, tunnels, water treatment, auxiliary cooling, workshops, fire and medical centre, sewage treatment plant, conveyors, access control, admin, etc.).
- Construction main ring (potable water, fire water, el. & telecom),
- Reservoirs and dams

The necessary intelligence to enable the functional use of the model shall be present, such as but not limited to; location data, KKS numbering mapped to the PBS, piping linked to the P&IDs. All terminal points and interfaces should be indicated with correct location information, to enable designers to identify the interfaces required for their design.

These requirements are also applicable to models transferred from all contractors. The 2-D general arrangement drawings, with the exception of the Location Plan, are generated from the 3-D model.

3.2.2 Location Plan

The location plan provides information required at the start of the project. The Location Plan is defined as a geographical map indicating all the infrastructure and natural resources of the proposed power station location. The information provided by the location plan includes details such as: environmental features, physical features and infrastructure such as towns, roads, railways, mines, dams, rivers, historical features, etc.

The Location Plan is produced to a smaller scale than the Site Layout Drawing, and is essentially a map of the station location and surrounding area (shows a larger area than the Site Layout Drawing). The general guideline for the scale is between 1:25,000 and 1:50,000.

3.2.3 Site Layout Drawing

The Site Layout Drawing is an important design control document that is required for all projects. The Site Layout Drawing is defined as a drawing showing the extent of the Eskom property and indicating the neighbouring properties. It shall be produced at a very early stage of the project as these drawings are used as part of the documentation for many of the licensing authority approvals (e.g. EIA, local municipalities, etc.). It shall indicate the centre point of the power station according to the World Geodetic System (WGS). It shall also indicate the grid according to the WGS. The local infrastructure is also to be indicated.

The Site Layout Drawing provides information for the proposed power station and the extent of the Eskom boundary. The information provided by the Site Layout Drawing includes details such as: property boundaries e.g. farm boundaries, environmental features, all existing infrastructure such as but not limited to graves, buildings, architectural or historical/heritage sites, wetlands, streams, dams, etc. and climatic conditions of the site.

The Site Layout Drawing provides significant information required to start off the project and must be updated as and when the information becomes known. This drawing must comply with the User Requirements Specification and must be kept up to date as the project progresses. The Site Layout Drawing shows more detail than the Location Plan, it only shows the site and adjacent properties. It is produced to a larger scale than the Location Plan. The scale is dependent on the size of the Eskom property/site.

3.2.4 Station Layout Drawing

The Station Layout is defined as a layout drawing indicating all the plant required for the safe erection, operation and maintenance of the proposed power station. The Station Layout Drawing provides the location and relationship between all major equipment, structural steel (columns and major steel),

building outlines, space allocation for equipment, construction requirements, operation and maintenance (O&M) requirements, and accessibility within the plant site. The Station Layout is a compilation of design information from all disciplines, including, but not limited to; buildings, equipment, foundations, material handling equipment, air quality conditioning services (NoX, FGD, etc.), underground utility, and all servitudes (e.g. cable, mechanical, etc.). Station Layout drawing is a critical design control document that is required for all projects and must be negotiated with and discussed with the Client Office.

3.2.5 General Arrangement Drawings

General Arrangement Drawings are typically plan and elevation views of each plant area that contains the layout information from all of the engineering disciplines. Composite detail drawings may be developed on projects that do not have a project 3-D model (e.g. existing plants). Composite detail drawings are created and then regularly updated using the appropriate CAD software to incorporate applicable information from the following drawings: GAs, structural steel, suspended floors, stairs and ladders, handrail/guardrail, foundation, architectural, site layout, underground utilities, piping, supports, tubing tray, cable tray, lighting, HVAC, material handling and equipment. Space allocation requirements for the operation and maintenance of equipment and engineered components must be included in this drawing type.

3.2.6 Design Data Exchange

All documents that are used to communicate arrangement design for the entire project life cycle shall be kept up-to-date and issued as necessary to support design and construction activities. To keep these documents up-to-date with the latest design information requires input and support from the entire project team and vendors. The discipline responsible for arrangement design in each building, structure or area, as per the contractual document, will use a controlled distribution to communicate the status of the arrangement design documents to the other disciplines and vendors for use in the layout of each discipline's and vendors plant components (e.g., piping, electrical tray, HVAC ducts, etc.):

All projects shall review arrangement design drawings as per [1] Design Review Procedure 474-1325 prior to each issue.

3.2.7 Engineering Change Procedure

The PEM shall be responsible for ensuring that the project disciplines communicate physical changes of components that affect arrangement design by implementing the requirements defined in the [2] Engineering Change Procedure N.PPZ 45-5. Managing design changes in a consistent manner by communicating, evaluating, and approving changes will control/minimise interferences at the site.

3.2.8 Arrangement Design Meetings

This subsection describes the content and objectives required for effective arrangement design meetings. The intent of these meetings is to provide a forum for communicating and resolving arrangement design issues between the participating disciplines and vendors in conjunction with supporting design deliverable schedules.

Arrangement design meetings are not intended to be the only method for communicating arrangement design issues between engineering disciplines. Continuous communication and teamwork are required to ensure that projects are able to continuously coordinate arrangement design issues successfully. In addition, the Project Engineering Manager (PEM), Lead Discipline Engineers (LDE's) and Lead Engineers, shall be responsible for ensuring that assigned project staff communicate arrangement design issues daily. During the initial arrangement design meeting, a method (for example, a Design Information Transmittal Document) shall be established for communicating interdisciplinary design information for the purpose of disseminating the information to appropriate project personnel.

3.2.8.1 Meeting Participants

During the early stage of a project, the PEM shall identify the project team members who will provide input for the various discipline arrangement design responsibilities. All representatives should attend the first meeting to understand the objectives of future meetings. The LDE Arrangement Design will be allocated to the project by the Manager System Design.

3.2.8.2 Meeting Responsibilities

The assigned responsibilities listed in the following subsections are intended to guide the project while making arrangement design decisions that will benefit the overall project.

3.2.8.2.1 Project Engineering Manager (PEM)

- Schedule and conduct the initial arrangement design meeting.
- Ensure that meetings result in a documented plan of action for arrangement design.
- Ensure that all arrangement design issues affecting the project are promptly resolved in the best interests of the project.
- Verify that arrangement design decisions are implemented.
- Enforce conformance to Standard for Design Change Management.
- Accountable for the results of the overall arrangement design process.

3.2.8.2.2 LDE Arrangement Design

- Generate a list of arrangement design meeting participants.
- Schedule arrangement design meetings as required.
- Develop meeting agendas for each meeting, with input from the group.
- Lead the arrangement design meeting; keep the attendees focused on the agenda.
- Document meeting discussions, decisions, deliverables, and action items.
- Distribute meeting minutes.
- Track and guide all action items to closure.
- Ensure that all arrangement design issues affecting the project are promptly resolved in the best interests of the project.
- Engage the PEM to resolve issues that affect project interests.
- Facilitate Constructability reviews. See Appendix-A Constructability Checklist.
- Enforce conformance to Standard for Design Change Management
- Accountable for the results of the overall arrangement design process.

3.2.8.2.3 Discipline Arrangement Design Participants

- Provide expertise and represent discipline interests.
- Be prepared to address items on the agenda and identify associated issues that may affect arrangement design at the overall project level.
- Follow up and complete task assignments, seeking additional expertise as needed.

- Address action items in a timely manner as jointly agreed upon during each meeting.
- Support decisions that are in the best interests of the overall project.

3.2.8.3 Meeting Schedule

- The first meeting shall occur within 30 days of project initiation. Subsequent meeting times shall be set either on a weekly or bi-weekly basis. Meetings to resolve specific issues shall be arranged on an ad hoc basis.
- Effective arrangement design meetings require that the following be addressed:
  - The project team adheres to a set agenda.
  - New issues that arise are discussed at the end of the meeting if time allows, or during another scheduled meeting for the parties affected.
  - Comprehensive minutes of meeting are maintained and distributed to all role-players.
  - An up-to-date action item list is maintained.
  - The agenda is organized to address subjects that involve the entire group first. Attendees may be dismissed when the discussion is completed on subjects that are associated with their design.

3.3 ARRANGEMENT DESIGN RESPONSIBILITIES

A discipline shall be assigned arrangement design responsibility for each building, structure, and yard area. The PEM shall assign responsibility for arrangement design to the discipline based on the scope of that particular discipline and the needs of the project.

3.3.1 Discipline LDE

Each discipline LDE is ultimately responsible for the entire design of his/her discipline/system, including the arrangement design (safety, operability, maintenance, etc.). The assigned arrangement design responsibilities shall thus include the following:

- Input of data into the 3-D model.
- Arrangement of all buildings, structures and equipment.
- Development of complete GA drawings.
- Issue/distribution of drawings.
- Ensure that the system arranged correctly in order to perform the required functions of that system.
- Performing an independent and comprehensive arrangement design review.
- Perform an independent comprehensive interference check within that particular system.
- Resolve all interferences within that particular system.
- Ensure that all specialities are catered for such as; manufacturability, constructability, operability, maintainability, accessibility and safety. See Appendix-A Constructability Checklist
- Ensure that all interfaces are available and accessible within the 3D model.

3.3.2 Arrangement Design LDE

Assigned responsibilities of the arrangement design LDE shall include the following:

- Provide the methodology, processes and tools and provide guidance in order to facilitate effective plant layout and arrangement.
- Generate the conceptual site layout during the feasibility phase of the project which provides integrated volumetric space allocation and major servitudes within which the various disciplines can start concept design (within 3D model).
- Provide support to engineering to facilitate optimal arrangement within the respective disciplines/plant areas, to ensure that all requirements/functions for the lifecycle of plant are met.
- The integration of 3D model of all the disciplines within the entire plant.
- Integrate the arrangement of all different disciplines / plant systems within the plant, throughout the lifecycle of project, ensuring that all the required interfaces and servitudes (tunnels, trenches, roads, pipe racks, etc.) are available as required.
- Perform inter-disciplinary interference detection throughout the entire plant and facilitate and manage resolution of interferences.
- Ensure that all interfaces/terminal points are indicated and identifiable within the integrated 3D model.
- Ensure that all specialities are catered for throughout the plant; manufacturability, constructability, operability, maintainability, accessibility and decommissioning and safety.
- Facilitate design reviews of the 3D model of the plant to ensure that the above is complied to and to ensure that there are no interferences.
- Be accountable for the final arrangement design of the total integrated plant

3.4 REVIEW GUIDELINES

The discipline assigned the arrangement design responsibility for each building, structure, or area will be responsible for performing independent and comprehensive arrangement design reviews. A combination of manual and electronic checking methods will be used for projects using a 3-D model. A manual/visual check will be used in conjunction with electronic interference checking software. The LDE Arrangement Design shall be responsible for the integration of the model and the integrated arrangement design reviews.

3.4.1 Arrangement Design Review Guidelines

The arrangement design review shall utilize the approved discipline's check sheet or an approved project-specific check sheet. The following are minimum requirements when performing arrangement design reviews, for initial and subsequent designs.

3.4.1.1 Civil/Structural Discipline

- Verify clearances between conduit, drain piping, curbing, and penetrations in foundations.
- Verify HVAC duct and equipment clearances with the following: other ducts, piping and supports, tubing tray, cable tray, structural and miscellaneous steel, building structure, equipment, access corridors, lifting and hoisting bays, platform headroom, and wall and floor penetrations.
- Verify material handling equipment installation and maintenance/access clearance for the following: cranes, conveyors, associated equipment, and conveyed material against structural and miscellaneous steel, building structure, tubing tray, cable tray, conduits, tripper pendants, ducts, floor and wall penetrations, pipe and supports, and non-stationary equipment.

- Verify structural steel, gusset plates, guardrail/handrail, ductwork, structure wall, and floor clearances with the following: equipment, steam and feed water piping and supports, and access/pull spaces associated with equipment.
- Verify clearances of vendor-furnished steel, platforms, stairs, walls, and roofs with integrated engineered components.
- Review equipment installation for constructability, maintenance, and accessibility for using a crane or monorail (if applicable).
- Ensure that building openings (external and internal) and elevators/lifting hatches are adequate for the installation and removal of equipment. If vertical restraints prevent installation, single or multi-leaf doors shall have removable transoms as required to support equipment installation and removal.

3.4.1.2 Electrical/Control and Instrumentation Discipline

- Verify cable tray and equipment clearances with the following: other tray, tray supports (if required), structural and miscellaneous steel, building structure, gusset plates, guardrail/handrail, equipment, access corridors, lifting and hoisting bays, platform headroom, wall and floor penetrations, HVAC ducts, piping and supports, tubing tray, electrical components, panels, and access/pull spaces associated with equipment.
- Review separation between electrical and C&I cabling.
- Verify that all electrical control connections to valve motor operators, instruments mounted on pipe, and temperature sensing elements are properly designed to account for the thermal movement of piping systems.
- Verify equipment installation and maintenance/access clearances with the following: structural steel, guardrail/handrail, building structure, piping and supports, tubing tray, cable tray, HVAC duct and equipment. Determine if building openings (external and internal) and elevators are adequate for the installation and removal of equipment. If vertical restraints prevent installation, single and multi-leaf doors shall have removable transoms as required to support equipment installation.
- Review equipment installation for constructability, maintenance, and accessibility.
- Refer to Subsections 3.4.1.5 and 3.4.1.6 for additional requirements, when checking clearances with pipe and gusset plates.
- Review separation between electrical and C&I cabling.

3.4.1.3 Mechanical/Chemical Discipline

- Verify pipe, valve, and accessory equipment/instrument clearance with the following: other piping, valves, and accessory equipment/instruments, valve operator/actuator pull spaces, all equipment including piping components, instrument bridle assemblies, pipe supports, cable tray and seismic tray supports, structural steel, gusset plates, guardrail/handrail, floors, access corridors, lifting and hoisting bays, platform headroom, electrical components, panels and access/pull spaces associated with equipment, equipment monorail and hoist space, space conditioning equipment and HVAC ducts, roll-up metal doors with overhead scroll and motor, wall and floor openings (consider thermal movements of piping).
- Review and consider thermal movement of all critical (hot or cryogenic) piping systems and equipment and verify clearances of these components from all engineered components and areas referenced above.

- Verify pipe support clearance with the following: structural steel, gusset plates, guardrail/handrail, column caps, building structure, piping, tubing tray, electrical tray, HVAC duct, and equipment.
- Verify thermometers, temperature elements, and other instrument/device clearances (including pull space) with the following: structural steel, guardrail/handrail, building structure, piping, tubing tray cable tray, HVAC duct, and equipment.
- Verify equipment installation and maintenance clearances with the following: structural steel, gusset plates, guardrail/handrail, building structure, piping, thermo wells, motor operators, control valves, tubing tray, electrical tray, HVAC duct, and equipment. Determine if building openings (external and internal) and elevators are adequate for the installation and removal of equipment. If vertical restraints prevent installation, all single and multi-leaf doors shall have removable transoms as required to support equipment installation (this is considered a best practice).
- Verify dimensions of all major equipment and associated components/modules, like the steam turbine including furnished equipment, piping, and valves; combustion turbine including furnished equipment, piping, ductwork, and modules; boilers including vendor-furnished equipment, piping, valves, supports, ductwork, and modules; and process equipment packages.
- Verify clearance of vendor-furnished steel, platforms, stairs, walls, and roofs with vendors engineered components.
- Review equipment installation for constructability, maintenance, and accessibility for using a crane or monorail (if applicable).
- Review location of large valves for adequate steel or crane availability for installation and maintenance.
- Refer to Subsections 3.4.1.5 and 3.4.1.6 for additional requirements when checking clearances with pipe and gusset plates.

3.4.1.4 Accessibility Review

- The discipline assigned arrangement design responsibility shall address accessibility during the design phase. Accessibility is defined as an approach to equipment, valves and instrumentation for the operation, maintenance, or removal of components. It is characterized by providing sufficient space to allow unobstructed access and/or reach for plant personnel. An accessibility review shall include the following, as a minimum:
- Adequate space for the maintenance and removal of equipment, valves, strainers, etc.
- Adequate accessibility to reach, operate, or view equipment, valve operators, and instrumentation without excessive use of ladders or overextended reach outside of guardrails/handrails.
- Review of access aisles and platforms for adequate headroom clearance, as required by [3] SANS 10400 The Application of the National Building Regulations.
- In areas where there are potential interfaces with other components, the Civil/Structural discipline shall provide estimated gusset plate locations and sizes and cross bracing locations and sizes to support timely clearance checks.

3.4.1.5 Gusset Plate and Cross Bracing Clearance Requirements

In areas where there are potential interfaces with other components, the Civil/Structural discipline shall provide estimated gusset plate locations and sizes and cross bracing locations and sizes to support timely clearance checks.

4. AUTHORISATION

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5. REVISIONS

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6. DEVELOPMENT TEAM

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

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APPENDIX A

Arrangement Design: Constructability Checklist

Item	Description
1	Is the construction/installation methodology clearly described in a formal document? (Listing all requirements, constraints, etc.)
2	Have the Contractor's yard / facilities / services been addressed? All contractors yards allocated.
3	Does the equipment fit in the location?
4	Are access roadway weight limits or clearances sufficient?
5	Are access roads to discharge, loading and unloading points and walkways segregated from road traffic?
6	Is there sufficient access for the equipment to be moved to the installation area? (Passages and doorways large enough, etc.)
7	Can the new equipment be installed in one piece or does it need to be supplied in sections?
8	Is the floor loading capacity sufficient to handle the equipment during installation?
9	Has the requirement for temporary piping, electrical supplies, fire protection, water diversion, been addressed?
10	Has a craneage plan been developed and is there sufficient area and height for cranes; movement during construction and laydown areas for erection and dismantling of cranes?
11	Is there sufficient area for other rigging equipment required?
12	Is there sufficient lay down area for equipment to be installed?
13	Have the supporting services been addressed? Compressed air, water, electrical power, temporary lighting, welding gases, heat treating services, etc.
14	Can the equipment be installed safely without affecting other operating equipment and generating units?
15	Are the overhead clearances sufficient for installation? E.g. Ensure clearance from high voltage power lines.
16	Are there means for construction personnel to lift the equipment and components?
17	Are there means for emergency egress?
18	Are the necessary fire protection and safety systems in place to enable construction?
19	Construction Sequence. Are there other construction activities or structures that are affected by the required construction access and laydown areas? Does the construction schedule/sequence take this into account?
20	Have the necessary health and safety requirements been met; sufficient provision for hook-ups at elevated areas, prevention and protection from falling hazards, ventilation and smoke extraction in confined areas where welding is performed, etc.?
21	Have all existing underground services been considered before excavation?
	Where blasting is required has the necessary consideration been given to the impact on existing operational equipment and other construction activities in the vicinity?
22	Are there any hazardous environmental conditions that require particular specialised PPE or specific precautionary actions (e.g. heat, noise, radiation, hazardous chemicals, gasses, Materials, etc.)?
23	Ensure that building openings (external and internal) and elevators/lifting hatches are adequate for the installation and removal of equipment.
24	Are the necessary measures in place to provide protection for sensitive equipment (e.g. environmental; moisture and dust or damage from surrounding construction activities)?