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1. INTRODUCTION

Technology advances in industry and its ease of use has resulted in huge improvements being made in the process control field. But, technological solutions often create issues that can offset these improvements, if the solution overlooks how the technology impacts control-room personnel. Thus the ability of a control room operator to carry out his task effectively is often hampered by the very technology that was implemented to assist them. Furthermore the environment in which the technology is implemented is as important for good plant performance and should be managed by senior management as any other business risk.

The design of a well-engineered control suite is achieved by applying systematic methods and people knowledge to evaluate and improve the interaction between individuals, technology and the organisation with the aim to create a working environment that contributes to healthy, effective and safe plant operation. It is globally recognised that efficient human interaction with the control system is as equally important as the technical specifications of the control system. The benefits of a well-engineered control suite manifests itself in the long term operation of the plant in areas like human performance and resource optimization and will impact positively on the overall business performance.

This guideline aims to provide practical guidance for the engineering process for the development of a control suite, eliminating common mistakes by following best practices and lessons learnt. The content of this guideline is considered reasonable, and it is recommended that the process described herein be applied, specifically to ensure that the requirement for a control suite is fulfilled and that the Eskom corporate identity requirements are complied with.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

This document provides practical guidance for the engineering process to be followed for consistent control suite development within the Generation Division. The guideline further defines the minimum requirements and deliverables that need to be generated to ensure compliance to the requirements specified.

The intent of this guideline is to align the different Eskom generating plants to follow a uniform and systematically approach to the design of control rooms and associated facilities to achieve the following results:

- Create a safe working environment within the control room by minimising the risk of work related illness and injury to the operator;
- Create a working environment that facilitates the safe operation of the plant by reducing the risk of human error;
- Create a functional environment allowing operators to focus on performing their tasks without disturbance during normal operation modes and emergency conditions;
- Create an environment of mutual support and teamwork;
- Create an environment that enables high level supervision;
- Create an aesthetically pleasing environment that indirectly leads to increased operator performance through self-fulfilment, motivation and cultural considerations.

It is recognised that the operator plays a critical role in the monitoring and supervising the behaviour of complex automated systems. This task as console operator, whose workload is often unpredictable, can

vary dramatically between periods of boredom waiting for something to happen and high activity when transient or emergency events arise. The consequences resulting from inappropriate operator action in control rooms, such as acts of omission, timing, sequencing etc. can potentially lead to unsafe conditions and loss of production. This guideline shall be used as a guide to create an environment limiting adverse human related factors thereby assisting the operator to perform at his/her optimum under diverse conditions.

2.1.2 Applicability

The guideline applies to the control suite design of all fossil and hydro power plants, specifically during the following opportunities:

- C&I System replacements;
- Return to service of mothballed plant;
- Building of new plant.

The development and upgrade of suite development on nuclear power plant is excluded from this requirement.

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] 240-53458811 Process Control Manual for Perform C&I

[2] ISO 11064 – 1 to 7 Ergonomic design of control centres

[3] SANS 10114-1 Interior lighting Part 1: Artificial lighting of interiors

[4] SANS 10114-2 Interior lighting Part 2: Emergency lighting

[5] 240-56364535 Architectural Technical Specification for Structures and other Buildings

[6] SANS 10400 The Application of the National Building Regulations

[7] Act 49 OF 1995 National Building Regulations and Building Standards Amendment Act

[8] 240-103414344 Summary of Corporate Identity Manual

[9] 240-56355731 Environmental Conditions For Process Control Electronic Equipment used at Power Stations

2.2.2 Informative

[10] Act 85 of 1993 Occupational Health and Safety Act

[11] SABS 0142-1 The Wiring of Premises

[12] UPTEC STS08 024 - UPPSALA University Paper “Use of Large Screen Displays in Nuclear Control Room”, E Harefors (2008)

2.3 DEFINITIONS

2.3.1 Work Space

The volume allocated to one or more persons on the work system to complete a work task.

2.3.2 Console/Workstation

Combination of work equipment (operating and administration) for a particular person in the work place.

2.3.3 Operational Zone

The immediate area around an operator where he/she has an assigned function and can exercise authority.

2.3.4 Work Environment

The physical, organizational, social and cultural factors surrounding a person in his/her work space.

2.3.5 Work Task

Activity required achieving an intended outcome of his/her work function.

2.3.6 Work System

One or more persons and equipment working together to perform his/her work function.

2.3.7 Control Room

Core functional entity, and its associated physical structure, where operators are stationed to carry out centralized control, monitoring and administrative responsibilities.

2.3.8 Control Suite

Group of functionally related rooms, co-located with the control room and including it, which houses the supporting functions to the control room, such as related offices, computer equipment rooms, rest areas and training rooms.

2.3.9 Human-performance design approach

Approach to interactive system development, focusing specifically on making systems usable, and emphasizing the role of human operators as control agents who maintain authority within a working system.

2.3.10 Primary user

Person engaged in those job functions normally associated with control centre activities.

2.3.11 Secondary user

Person that occasionally uses or maintains the control centre.

2.3.12 Ergonomics

Ergonomics is the science of humans' relationship with the working environment. It considers all aspects of human interaction with systems and machines and its application takes many forms, which include the working environment, the social environment, physical aspects of equipment design, information engineering and psychological aspects of information transfer.

2.3.13 Anthropometrics

Physical attributes, such as body size, reach, and visual capabilities, are relatively easy to document.

2.3.14 Disclosure Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
AFC	Approval for Construction
BU	Business Unit
C&I	Control and Instrumentation
CED	Capital Expansion Department
CO	Client Office
CoE	Centre of Excellence
HMI	Human Machine Interface
HVAC	Heating, Ventilation and Air Conditioning
IT	Information Technology
LDE	Lead Design Engineer
URS	User Requirement Specification
VDU	Visual Display Unit

2.5 ROLES AND RESPONSIBILITIES

The Lead Design Engineer shall be responsible to ensure that this guideline is implemented on applicable projects.

The C&I Plant CoE Manager (or his delegate) will check compliance to this guideline during the design review process.

2.6 PROCESS FOR MONITORING

The document shall be updated in accordance with the Eskom document review process or as business needs change.

2.7 RELATED/SUPPORTING DOCUMENTS

See section 2.2

3. DESIGN GUIDELINES

3.1 TRENDS IN CONTROL ROOM DEVELOPMENT

Across the globe the practise regarding the “new era” control rooms are to combine all or a number of associated, plant operating consoles under a common roof, thereby creating a central control room with the aim of achieving the following:

- Improved communications between operational staff;
- Reduced manpower costs in terms of supervision requirements;
- Reduced construction costs;
- Providing one central point of focus for the entire plant operations.

Whilst achieving the above objectives, it is important to consider the individual operator within this environment with the aim of improving productivity and effectiveness. It therefore stands to reason that an operator, who is comfortable in his working environment and an operator whose working environment support's his tasks, is both a productive and efficient operator.

Although it is recognised that conditions and requirements vary from site to site, there are two main factors that must be considered and carefully designed when considering a new or upgraded control room, namely:

- Equipment and tools to perform the tasks;
- The "human factor".

The emphasis of this guideline is placed on the peripheral tools required by the operator to perform his/her task effectively such as:

- Console design;
- Work space design;
- Lighting design;
- Air conditioning design;
- Furniture & storage design;
- Corporate identity compliance.

The human factor design approach can be summarised as follows;

"An approach to interactive system development, focusing specifically on making systems usable, and emphasizing the role of human operators as control agents who maintain authority within a working system".

The intent of this guideline is thus not to specify any process control, monitoring or supervisory systems but rather to provide a guide for the development of the control suite design for new plant or the placement of the control system at the point of human machine interface (HMI).

3.2 CONTROL SUITE ENGINEERING PROCESS

The process described below varies slightly for a new plant, mothballed plant and a plant going through midlife refurbishment. For a new plant the best practices in terms of design can more easily be achieved since everything is new and the concept is not hampered by existing structures, layouts or staff that are used to the routine way of operating. A mothballed plant might not have existing control rooms that can be utilised and new area/s needs to be identified and their viability investigated. An added advantage is the fact that significant mechanical and civil upgrades form part of the overall scope and the control rooms can then be planned in co-ordination with these activities.

Plants going through a midlife refurbishment is perhaps the most difficult to change mainly because of time pressures for implementation of the new system, structural constrains, resistance of operating personnel to change, the often lengthy duration from the first unit to the last as well as the implementation sequence. The typical six pack station is currently equipped with more than one control room and the latest trend is to centralise all the control functions which has added advantages in terms of resource optimization and life cycle cost but can have detrimental effects if not designed and implemented properly.

3.2.1 Functional and Task Requirement Phase

The first step in the engineering process is to determine the functional and task requirements, which will form the basis of the conceptual and detail design of the new control suite. The functional requirements

specify the specific functionality thereof within the bigger organisation while the task requirements identify the individual tasks that are being performed directly inside the control room or as a result of interaction with the operating personnel.

3.2.1.1 Process

The following describe the recommended process to be followed for this phase. It further includes the relevant aspects that need to be considered in each of the defined steps to be followed.

3.2.1.1.1 Establishment of a project team and executive decision committee

The design of a control suite is generally complex, involving, for example, multiple users, conflicting objectives, ambitious schedules and the incorporation of a diversity of new technologies and methodologies. It is thus essential that a project team be appointed to drive the engineering process for the development of the control suite. The team composition will vary depending on the roles, responsibilities and experience of personnel at the power station and shall include representatives of all the different primary and secondary users as well as the main stakeholders thereof. The actual combinations of disciplines to be included in the team may also vary depending on the overall project scope or design phase. This team may include system and process engineers, agronomists, architects and industrial designers. For existing plant systems, users or user representatives shall be included as members of the team. For new plant, both experienced and future users shall form part of the design team.

Dependant on the magnitude and complexity of the project, it is proposed that the project team consists of at least of the following members:

- BU management representative;
- BU operating or production manager;
- Project manager;
- BU C&I engineering manager;
- BU C&I engineers or technicians;
- Process control consultant;
- Operations consultant;
- Senior BU operations personnel;
- Contracted company for the design process, encompassing technical staff as required by the complexity of the project;
- Part time engineering input on Civil, Electrical and HVAC.

It is also important to realise that a control room is much more than just a building where humans interact with machines or lately with computers. For effective operations the control room has to be designed according to sound human performance principles to bring out the best in the humans. These dimensions necessitate the use of specialised personnel that is not that readily available within the organisation. It is recommended to appoint a suitable external company that specialises in the design of control rooms at an early stage of the project to be part of the identified project team. The use of an architectural company is not recommended as there are a significant amount of human engineering factors that could be neglected with detrimental effects on the outcome of the actual design.

The project team, including the users, shall be available throughout the project's life cycle. Team participation is essential and should be planned and specified in detail at the beginning of the project. Further the project team must continuously review and evaluate the information captured. The process

of evaluation must be repeated until the interactions between operators and designed objects achieve their functional requirements and objectives.

The role of the team is also to facilitate the development concepts to management to make an informed decision and it is imperative that the team research the trends with regards to control room engineering. The petrochemical industry is a good point to start, as they have already gone through groundbreaking experiences in terms of control room engineering. In Generation there have also been several stations that went through refurbishment and good practices can be enhanced while mistakes can be eradicated at this early stage.

It's also recommended that a decision committee that have executive powers be established. This committee must meet on an ad hoc basis to guide the project team as well as to make crucial decisions in terms of the subsequent steps in the process. The BU can decide for itself on the make-up of the committee but it is essential that the committee is specialised in terms of technical capabilities but dynamic enough to enhance potential change. The committee should also have management representation, often the BU manager himself, to ensure strategic input in the final requirements.

3.2.1.1.2 Identification of the users and stakeholders of the control room

A clear distinction must be made between the primary users, secondary users, temporary stakeholders and the long term stakeholders of the control suite. The primary users is predominantly the console operating personnel while the secondary users includes supervisory staff, other plant operators, maintenance personnel and engineering personnel that interface with the console operator on a regular basis. There are also infrequent visitors to the control room, both from internal and external to the station which needs has to be catered for. The temporary stakeholders are parties that hold a vested interest in the control suite in terms of the design and construction thereof to effectively execute the commissioning of the control system. These are typically the refurbishment or engineering team, contractors and corporate support functions. Management is identified as a long term stakeholder as they are ultimately accountable for the business.

The project team will also have to identify any other unique stakeholders or users to ensure that their relevant needs are addressed.

3.2.1.1.3 Determining the needs of the users and stakeholders

It must be realised that the needs of the different parties will most probably be conflicting in certain areas. This is especially true for a station going through refurbishment where the operators are resisting the changes associated with the new control system, the implementation of new control philosophies and where management want to capitalise on the benefits of new technology. The latest trend is to house all the control functions in a centralised control suite which have significant benefits in terms of resource optimisation and life cycle costs. This is however a considerable change for the older generation of operators and it therefore needs to be managed with extreme care.

In terms of the users the project team shall identify the following:

- Amount of personnel that are currently permanently situated in the respective control suites, the tasks they perform and the typical equipment they require to perform these tasks.
- Amount of personnel that is based in the control room but not having to perform tasks inside it.
- Amount of personnel that have to interface with all the above mentioned personnel, the frequency thereof as well as the type of communication that would be suitable to facilitate effective interaction.
- Limitations in terms of distance to the plant.

In terms of the **stakeholders** project team shall identify the following:

- The specific and relevant business unit goals.
- The specific constraints in terms of the budget.
- The level of automation versus manual operation and/or the envisaged changes thereof.
- The availability of online information versus local information that have to be collected by means of check-sheets.
- The organisational structure and culture.
- Operating and maintenance philosophies.
- Profile of existing operating personnel where applicable.
- Specific design of the station especially for new projects.
- The refurbishment programme and sequence of refurbishment.
- Corporate requirements and standards.

3.2.1.1.4 Consolidation of requirements

After the requirements have been established, the project team determine the most important criteria applicable to the specific BU. This is done by means of applying a weight allocation to each criterion by predicting the long term impact on the BU if this specific requirement is not addressed. Once the requirements have been verified it can be consolidated and ranked in terms of importance. The results are then validated and buy in obtained through a process of collaboration and consent from the decision committee before the next step.

There is however pitfalls in this process that needs to be taken into consideration. These are:

- The project team might encounter significant resistance to the change especially from people that are used to the way they operated over many years and would like to keep it the same. This is more probable to happen when the there are changes to the location of the control room and/or amount of control rooms. The centralisation of control rooms into one control facility for the plant is the most resistant change as it influences the work environment of many of the operating personnel. Thus during the needs analysis process, the operator age profile must be considered, as the typical C&I replacement project is executed over many years and many of the current operating personnel might not be part thereof due to their age.
- Management might not see the big picture and understand all the advantages and disadvantages of the decision they take unless they are fully informed to do so. It is therefore important that the project team ensure that sufficient information is available for management to understand the intricacies of modern control rooms. It must also be highlighted that most of the disadvantages of a centralised control room can be eliminated if it is properly designed in terms of both ergonomic and anthropometric principles. To assist with the facilitation of the decision process it is essential that the services of company that specialises in control room design and development be used.

To eliminate or at least to reduce the impact of these pitfalls, it is recommended that the following recommendations and tools highlighted below be utilised.

a. <u>Change process</u>

The tendency is that operating personnel will resist change unless it is facilitated through a change process in which they are transformed to buy in to the mutual benefits thereof. It cannot be assumed that the use of advanced technology, for example a sophisticated control system, will automatically achieve benefits if the potential cost-benefit to users of the system are not considered or quantified. This

might include a more interesting job in a more conducive environment with more responsibility and autonomy. The fear of change is normally due to perception about the invasion of privacy, excessive noise levels etc. These concerns are valid but it can be eradicated by means of a proper design concept and operating personnel need to understand it accordingly.

The project team should identify a few of the stronger operating personnel and involve them with the process. A typical method to start with is for them to visit other power station where different control room concepts have already been implemented, talk to the operating personnel working there and experience first-hand how it will be. This will also give them the change to identify possible improvement on their own concept designs so that the end product is a customised product based on principles that work. The project team should also be aware of the pitfalls of combined control rooms and ensure that the design is done on sound principles eradicating all the negative factors thereof.

b. Risk management

There is obviously a greater collective risk associated with centralised versus individual control rooms and this need to be understood fully so that the necessary mitigating factors can be taken into consideration. It's further recognised that some of the risks will automatically be eradicated if the design is done according to the principles described in this document.

The control room is often designed to function well under normal conditions which make up most of the time. It is however the non-routine events and the abnormal events that needs special attention and might require higher management involvement. Management need to understand that the choice made in the functional and task phase necessitates certain downstream requirements in terms of the detail design and required equipment like communication mediums.

Non-routine events are defined as those that occur from time to time but are not part of the day to day operation. These events are normally not planned for or planned for long in advance, which impacts on the smooth operation of the plant predominantly due to more than normal activities within the control room. These activities lead to more communication and have the potential of additional personnel requirements, which require interaction with the panel operator. This varies between the different business units, depending on the plant operating mode. (E.g. base load versus a peak load). Typical examples of non-routine events are:

- Unit trips;
- Unit start-ups (hot, warm or cold);
- Re-commissioning after general overhauls.

The severity of these additional activities can be catered for by minimising and keeping them out of the control room as far as possible. This is possible by having thorough communication mechanisms and an organisational culture to not directly interfere with the consol operator unless required. Re-commissioning can be planned for and executed from an alternative location which will eliminate the disturbances to other operating units.

Abnormal events have even a more severe impact on the routine operations in the control room and stations are normally less prepared in dealing with it. Typical examples of abnormal events are:

- Multiple unit trips;
- Re-commissioning of the first unit after the major refurbishment;
- Installation of the equipment, subsequent to the first unit;
- Fires in the control room or in areas affecting the operation thereof;
- Major damage to the plant.

The adverse effects of the above mentioned factors can be eliminated in the downstream designs but it is important that the project team take cognisance thereof.

c. Application of a human performance design approach

The combination of humans and machines within the organization and environment supporting it forms a complex system that needs to be optimized, in order to gain smooth interaction. This optimization is achieved by developing solutions that emphasize and maximize the strengths, features and capabilities of both humans and machines in a complementary fashion. The human component, the machine (hardware and software), the work environment, and the control (operation and management) shall be harmoniously integrated during all phases of the design process. The activities where a human performance design approach may be relevant are planning, conceptual and detailed design, assembly and construction, commissioning, user training and operations.

A human performance design approach needs to be integrated into the traditional function orientated design approach. This will allow for certain human characteristics to be considered as the basis of the design requirements which will underlay the final design specification. These characteristics shall not only include basic physical capabilities or limitations, but shall also emphasize the cognitive strengths of humans (such as perceptual ability, problem solving and decision making). In addition, knowledge about how operators feel and interact with operations and management, as well with design objects that include machines, the environment and so on, shall be considered. For large and highly automated system the more subtle psychological demands may also require special attention.

Where physically challenged people are assigned to work or visiting the control suite, the design shall accommodate their specific needs.

d. User participation

User participation throughout the design process is essential to optimize long-term human-machine interaction by instilling a sense of ownership in the design. A structured approach should be followed involving both current users and potential new users of the facilities. Experienced users can offer valuable empirical contributions to the control suite design. Their practical experience is not always documented or well known by designers. Operational feedback derived from user participation should be analyzed to identify previous design successes and shortcomings.

3.2.1.1.5 Finalisation of the functional and task requirements

Once the inputs from the above mentioned processes have been consolidated the project team can now identify the potential options for the location and functionality of the control suite/s. At this level it is important to determine potential functional groupings, un-bundle of functions or integration of certain functions within others. Once the options are clearly defined it needs to be tested against the consolidate business needs and after considering of the associated risks the most suitable alternative should be recommended for management decision. This approved decision forms the basis for the development of the conceptual design and subsequent detail design.

3.2.1.2 Minimum requirements

It is recommended that power station follows at least the following principles during the functional and task specification phase:

- Appointment of a project leader and a multidisciplinary team
- High level sponsorship and management commitment
- Selection of most suitable alternative only after proper collaboration of benefits and disadvantages thereof

- Selection of a suitable external consulting company to assist in the engineering process

3.2.1.3 Deliverables

The deliverables of the functional and task requirement phase are the following

- A documented business case describing the options considered and the reasoning for rejecting and selecting the relevant option/s.
- A documented user requirement specification to be used for the conceptual design phase especially to define the scope of work for the external consulting company that will be employed to perform or assist with this phase

3.2.2 Conceptual Design Phase

In this phase a comprehensive design concept of the control suit is developed that satisfies the allocated functional and task requirements as defined in the previous phase. The conceptual design shall include the physical attributes of the control suite, its layout, furnishing and any special amenities, for example rest rooms, libraries, meeting rooms. The conceptual design shall also include the proposed operator interface, such as displays, work station or console design and communications.

3.2.2.1 Process

3.2.2.1.1 Clarification of the design brief

An initial site meeting shall be held involving all proposed project staff including the consulting company in order to table and discuss the design brief. A purchase order entitled “Upgrade of existing control room” is hardly sufficient for a consulting company to start developing solutions without the boundaries and expectations being discussed.

This forum shall be used to discuss and outline the following:

- User requirements and functionality goals;
- Standards and other formal Eskom documentation;
- Applicable company policies;
- Definition of the term “normal operations” and the implications applicable to the site;
- Definition of the term “emergency or abnormal operations” and the implications applicable to the site;
- Definition of the term “maintenance outage” and the implications applicable to the site;
- Applicable technical information pertaining to the control system especially the HMI aspects;
- Analysis and discussion of similar installations at other BU’s, highlighting both positive and negative aspects;
- Fire protection philosophies for manned and unmanned areas;
- Various relevant requirements or constraints;
- Review of initial documents such as elementary designs, documented deliverables;
- Budget constraints within a rough order of magnitude;
- Review of previous work and concepts implemented by the consulting company.

The above mentioned forum shall be recorded and used as the initial design brief. It is not the intention of this forum to define the solution at this stage.

3.2.2.1.2 Site survey

The consulting company shall be required to perform detailed site surveys in the following areas:

- Evaluation of existing operator conditions in the case of a control room upgrade project;
- Detailed notes, measurements and photographic survey of the relevant areas;
- A manpower and equipment matrix in conjunction with BU;
- Maintenance organisation.

Site survey information forms a crucial role in evaluating and understanding the individual anomalies that must be addressed within the control room.

a. Operator conditions

The main areas of focus for the operator evaluation are as follows:

- Controls;
- Visual Displays;
- Work Space;
- Seating;
- Communications;
- Movement around the control console;
- Documentation requirements;
- Emergency Requirements;
- Personal belongings;
- Bathrooms;
- Kitchen/eating area;
- Relaxation area;
- Thermal comfort;
- Lighting;
- Auditory Environment;
- Ambience;
- General (soft issues & comments);

A typical questionnaire document is attached in ***Appendix A***

The aim of the operator site survey is to determine the effect of existing conditions i.e. aspects of the control room that are either found to be liked or disliked. Based on the results, the design process will be able to focus on the positive points and eradicate the negative points.

b. Notes, measurements and photo survey

General notes of the environment must be captured during this survey such as dust ingress, noise factors, access constraints etc.

Verification of measurements and layouts to existing drawings must be cross checked as drawings are often old and may not represent modifications and additions.

A photographic survey of the area shall be performed to facilitate ease of reference during conceptual design.

c. Manpower and equipment matrix

In conjunction with the BU, the consulting company shall develop a matrix defining the equipment and manpower requirements for the area concerned. It is vital that the consulting company develops a clear understanding of the requirements in order to allocate the appropriate spacing.

Commonly termed “job assignment” the following points shall be discussed and understood by the consulting company as part of the manpower and equipment matrix:

- Functional job requirements;
- Information and data requirements;
- Required tools, physical space and facilities;
- Conditions where tasks are to be performed.

The preliminary work organisation structure shall comprise the following elements:

- Lines of authority and responsibility;
- Team structures and co-operation between these structures;
- Union/management agreements where applicable;
- Training requirements and shift patterns
- Regulatory requirements;
- Physical proximities;
- Intercommunication requirements;
- Secondary user requirements.

A typical example of the equipment and responsibility matrix is attached in ***Appendix B***.

3.2.2.1.3 Areas of review for the conceptual design

The following areas, where applicable, shall be reviewed and conceptually designed during this phase of the process:

- Control room;
- Meeting room;
- Shift supervisors office;
- Additional supervisory offices as required;
- Training facility;
- Equipment room;
- Administrative offices;
- Maintenance room;
- Rest/relaxation room;
- Smoking room;
- Eating area;

- Kitchen;
- Locker rooms and toilets;
- Library for manuals and drawings;
- Permit to work issuing location;
- Visitor's gallery.

Within these areas the following aspects shall be considered:

- Determine the usable spaces;
- Visual display units such as monitors, large screens and mimic boards;
- Identify furniture and equipment to be accommodated within the control room space;
- Specify circulation requirements for staff and visitors;
- Maintenance access requirements;
- Control consoles and workstations;
- Equipment racks;
- Storage both in and around the work area;
- Fire protection;
- Notice board;
- Entrance and exits;
- General plant overview visual display units (if required);
- Desk storage, filling cabinets and bookcases;
- Printer areas, photocopying and facsimile machines.

3.2.2.1.4 Development of preliminary designs

The results captured during site survey's and development of the design brief discussions shall be restructured systematically into a series of design concepts and preliminary specifications encompassing all intended aspects of the control suite's physical and functional characteristics. The manpower and equipment matrix together with the discussions around operator job assignment criteria shall form a basis for determining the control room layout and work space requirements.

The following aspects shall be clearly presented in the form of two dimensional drawings and narrative documentation:

a. Conceptual design specifications, including dimensioned preliminary layouts;
b. Significant known design constraints, such as budget, location, safety, styling, fail-safe redundancy;
c. Understanding, materials, pre-determined vendor control systems, sub systems etc;
d. Applicable regulatory and Eskom related standards, practices, codes and local conditions;
e. Functional links;
f. Operational links within functional areas;
g. Space allocations;
h. Control room arrangement including adjacent amenities;

i. Control room layout;
j. Control room layout indicating lines of traffic movement;
k. Workstation / console layout and basic dimensions;
l. Displays and controls;
m. Preliminary lighting layout;
n. Preliminary power layout;
o. Fire protection requirements;
p. Security and access controls;
q. Environnemental conditions;
r. Operational and supervisory elements;
s. Communications and information channels;

This process shall result in several design ideas that can be individually appraised and potentially combined to form an enhanced conceptual design. The appraisal process shall be a combined effort between all parties of the project team.

Elements of the above process may be required to be re-visited by the consulting company in the event of the BU's rejection of part or all of the proposed concepts.

3.2.2.1.5 Improve design through interaction

Design improvement is inherently interactive in practice. Evaluation shall be repeated until the interaction between operators and designed objectives achieve their functional requirements and objectives. Establishing the validity of a single element of the design in isolation does not guarantee that the final system design will be validated. Any modification can cause undesirable effects even if the modification itself is valid. There shall thus be a formal process that defines and control scope changes in the design of all aspects of the control suite.

It should be noted that users, either consciously or unconsciously, may adapt their behavior to modifications, and that such behavioral changes may not be consistent with good ergonomic practice. The incorporation of operational experience/feedback is of particular importance in this iterative process.

3.2.2.1.6 Approval of conceptual design

Once general approval has been obtained from the project team, the consulting company shall develop three dimensional computer generated graphics of the proposed control room. It must be noted that interpretation of two dimensional drawings will vary from individual to individual thereby allowing the possibility of misconceptions to arise. Three dimensional graphics shall be developed such that no misinterpretation can be construed. Equally, three dimensional graphics shall be developed such that they present a true reflection of the proposed finished product. Such graphics form an integral component of the conceptual design package deliverables.

Final approval of the conceptual design package shall be awarded on approval by the project team. Documentation and drawings shall contain sufficient information to allow the BU to submit the package for lump sum pricing of the detailed engineering phase and budget pricing for the supply and installation phase.

3.2.2.2 Minimum requirements

It is recommended that the BU follows at least the following principles during the conceptual design phase:

- Appointment of a project leader and team;
- High level sponsorship and management commitment;
- Selection of a suitable external consulting company for the concept design;
- Development of the design brief;
- Detail site survey;
- Operator evaluation, including a manpower and equipment matrix;
- Development of the concept design, and approval there-off.

3.2.2.3 Deliverables

The deliverable of this phase is a complete conceptual design package, consisting of two dimensional drawings and three dimensional computer generated graphics of the control suite. The design documentation shall contain sufficient information to allow the BU to submit the package for lump sum pricing of the detailed engineering phase and budget pricing for the supply and installation phase.

Appendix C refers to a typical conceptual design delivery matrix, which highlights the relevant items to be considered as well as what should be delivered before entering the detail design phase.

3.2.3 Detailed Design Phase

The purpose of this phase is to develop the detailed design specification for the control suite. The design specification should be of sufficient detail to enable the estimation and detail planning of the control suite construction. The design specification shall also be suitable for initiating requests for quotations for implementation.

The approved conceptual design package, containing layout drawings, three dimensional graphic representation of the room and a list of finishes forms the design base for this phase.

3.2.3.1 Process

The approved conceptual design package, containing layout drawings, three dimensional graphic representation of the room and a list of finishes forms the design base for this phase. The design is further based on industry standards and appropriate ergonomic data that is appropriate for the anticipated scope of the work, complexity, available resources, schedule, and budget. This involves the following process:

3.2.3.1.1 Control suite arrangement

To develop design specifications for the control suite arrangement, the following activities shall be performed:

- Confirm functional areas making up the control suite;
- Determine the space requirement for each functional areas;
- Confirm suitability of the planned site, for example space restrictions, local hazards, environment, etc;
- Acquire current copies of all standards, codes, user policies and guidelines, etc;
- Verify availability of materials.

Note: The determination of the operational links between the functional areas and the development of the control suite layout during the concept phase are used as the basis for the design.

3.2.3.1.2 Control room layout

The following have to be undertaken to design the control room properly:

- Determine the usable space;
- Identify the furniture and equipment to be accommodated within the control room space;
- Determine operational links which need to be provided between items to be housed within the control room, including personnel;
- Specify circulation requirements for staff and visitors;
- Specify maintenance access requirements

Note: The control room layout is based on the task requirements and job design defined in the concept phase, including population characteristics, communication, equipment sharing and team work.

3.2.3.1.3 Workstation layout and dimensions

To determine the workstation layout and dimensions, the following engineering tasks must be conducted:

- Analyse and clarify the tasks to be undertaken at the workstation;
- Identify the functional elements of the workstation;
- Develop workstation layout and dimensions.

Note: Workstation refers to operating consoles and other work areas.

3.2.3.1.4 Designs of displays and controls

The design specification of the displays and controls that will be used within the control room is developed in this step. It shall ensure that it satisfy the functional specifications of the task requirements defined.

Displays and controls may involve a number of hardware and software options, including:

- Conventional instruments (push buttons, indicators, recorders etc.)
- Visual display units.

Note: In addition to the basic ergonomic requirements (optimal viewing angle etc.), it is essential that special attention is given to cognitive characteristics (optimal work-load etc.) of the users. The density, content and quality of information and the timely presentation are critical design issues. Hence the importance to select the devices best suited to the control actions.

3.2.3.1.5 Environmental design

The proposed design specifications have to meet ergonomic criteria, particularly with regard to a safe and comfortable working environment. The aspects to be considered are:

- Thermal environment;
- Air distribution and quality environment;
- Lighting environment;
- Acoustical environment;
- Vibration.

3.2.3.1.6 Validate detail design package

The detail design package developed in this phase shall be formally validated to ensure that it conforms to the user's needs.

3.2.3.2 Minimum requirements

Where relevant, the detailed design shall include the following:

- Detailed design architectural drawings
- Detailed design civil and structural drawings and calculations
- Electrical drawings for power distribution and lighting circuitry (including lx level calculations)
- HVAC drawings and detailed specifications
- Detailed fire protection drawings and specifications
- Material selection including finishes, paint specs, lights, console material and chair specifications etc.
- Instrumentation details such as equipment specifications and wiring schedules
- Detailed project schedule and execution plan
- Detailed supply and installation costing.

All drawings and documentation shall be submitted to Eskom for "Approved for Construction (AFC)" approval by the relevant departments.

The importance of developing a detailed engineering package is crucial in assigning a detailed scope of work complete with detailed drawings to the prospective supply, installation and construction contractors. Should this step be omitted, areas of ambiguity and uncertainty will arise during construction.

3.2.3.3 Deliverables

The deliverable of this phase is a detailed engineering package, consisting of a detailed scope of work complete with detailed drawings. Should this step be omitted, areas of ambiguity and uncertainty will arise during construction.

Appendix D refers to a typical design delivery matrix, which highlights the relevant items to be considered as well as what should be delivered before entering the implementation phase.

3.2.4 Implementation Phase

The supply and installation of the control suite is often a complex activity requiring careful co-ordination between several contractors and site activities. Where an upgrade to an existing control room is being executed, it is of paramount importance that the construction activities cause minimal disturbance to the operation of the plant. For new build plant this phase needs to be integrated in the overall project plan to ensure scope completeness, execution planning and that the inter-relation between the different contractors are identified. Integration of multiple contractors into an overall project plan is vital, to allow for correct phasing of project activities, so that the implementation phase is only started when the detailed design phase is complete.

3.2.4.1 Areas of Responsibility

Construction activities should generally reside under a single point of authority namely a singular contracting company in order to co-ordinate activities effectively.

Construction activities can include all, or a combination of the following;

- Structural;
- Civil;
- Electrical, plumbing and HVAC;
- Instrumentation and IT requirements;
- Fire protection;
- Interior architectural;
- Furniture, console manufacture and installation;
- Shop fitting activities.

Structural and civil activities can be separated from the overall scope. However, this introduces areas of uncertainty such as the installation of electrical conduit, accuracy of building works, plumbing points, LAN connection points etc. It is therefore strongly suggested that the activities of the civil contractor are managed by the control suite installation contractor who, in turn, must ensure accuracy and compliance with the detailed design drawings.

Where contractual tasks are split between two or more contractors it is essential that a responsibility matrix is developed and agreed upon prior to commencement of activities. It is the responsibility of the Project Manager to ensure that all activities are executed and completed as per the assigned responsibilities. The example responsibility matrix as illustrated in ***Appendix E*** can be used to facilitate and finalize the interaction between the different contractors.

3.2.4.2 Manufacturing Inspection

The manufacturing phase and quality control plant must make provision for the witness any inspection of equipment or systems that are to be incorporated into the control room. Typically this would include an inspection of the control consoles prior to shipment from the manufacturing contractor. The aim of inspection is to reduce the timing and disturbance of construction activities on site.

The installation phase must be co-ordinated such that contractors, where possible, are not manufacturing or modifying equipment once delivered to site. The aim of the fitment phase must be such that equipment is simply assembled, fitted and connected in a modular format.

3.2.4.3 Working within an Existing Control Room

Construction activities within an existing control room will inherently cause disturbance to operators working within the space. Careful planning and project execution is essential to limit this disturbance as far as possible. Typically this will include the erection of temporary hoardings separating the two activities. Unfortunately the area must be viewed as a construction site and disturbances will occur, however, if planned efficiently with close co-operation between station staff and the contractor, these disturbances can be reduced significantly.

Where multiple units will be controlled from a combined control room the concept of a separate commissioning facility is recommended.

This entails that the respective units will be commissioned from a separate room, and plant control from the combined control room is only implemented after a unit is fully commissioned. This will reduce the amount of staff required to be in the control room during commissioning, thus limiting the disturbance to the plant operators of other units.

3.2.4.4 Risk of Working on Operational Plant

Construction activities within an existing control room also introduce risk to plant operation, which requires a detail risk assessment before any work commence. Unfortunately the area must be viewed

as an operational zone and if planned efficiently with close co-operation between station staff and the contractor, this risk can be reduced significantly.

3.2.4.5 Additional Scope

No matter how well planned and engineered the project has been prior to installation, there will always be requests for additional items such as shelves, hooks, cupboards, socket outlets during installation. Each request shall be evaluated by the project team as part of a change management process and if approved the subsequent instructions issued to the installation contractor.

3.2.4.6 Commissioning

The installation contractor shall be responsible for the commissioning of equipment that falls within the scope of work. Commissioning shall be performed with the assistance of the project team.

3.2.4.7 Punch Listing and Final Acceptance

The project team shall be responsible for the final quality of the installation. Punch listing shall be done in conjunction with the client and installation contractor. Items requiring rectification shall be entered onto an official defects list and officially transmitted to the installation contractor.

3.2.5 Operational Feedback Phase

Upon completion and commissioning of the control suite, operational feedback is used to continue checking on the validity of the design of the control suite during its lifespan. This is achieved by collecting and examining operational feedback information after the start of the system operation.

A post-commissioning audit with the primary goal of recording both the design successes and shortcomings should be performed. The resulting record (learning experience) should be a valuable resource for influencing future projects and evaluation studies.

3.3 DESIGN CONSIDERATIONS

This section covers the ergonomic design principles for the control suite, and more specifically, the various arrangements of equipment and spaces design in a control suite. The principles are based on the analysis of functions and tasks that have to be supported by the control suite. They include identifying functional areas, estimating space requirements, determining operational links between functional areas in the development of layouts for the control suite.

3.3.1 Arrangement of the Control Room

The following covers the ergonomic design principles of control rooms and the items listed below are intended to be used as a guide recognizing, that each application will contain individual variations and constraints.

3.3.1.1 Objective for the Arrangement of Control Rooms

The objectives for the successful arrangement of the control room are to design the work system in consistency with human capabilities, limitations and needs.

3.3.1.2 Location of the Control Room

In order to determine the appropriate location of the control room on a site, the following interacting ergonomic, environmental, technical and additional aspects must be considered:

3.3.1.2.1 Ergonomic;

- Visibility requirements; in other words, if it is important that a process or site/area is visible to particular operations, that work area should be located such that visual access is unobstructed;
- Distances between the control room, process plant, local control facilities and workstations;
- Control suite accessibility and emergency exits;
- Job assignments, including requirements concerning communication and interpersonal interactions;
- Operator interaction with equipment required to perform the job assignment;
- Consideration of the movement of operators, other station personnel and visitors within the control room;
- Consideration of adequate space for service and maintenance activities.

3.3.1.2.2 Environmental;

- Adequate light and the effect of windows;
- Adequate control of room temperature;
- Adequate protection against or avoidance of high noise levels;
- Adequate protection against or avoidance of draught, wind, dust and fumes;
- Adequate protection against or avoidance of vibrating environments;
- In the case of alternating electromagnetic fields of external equipment, workplaces should be located such as to minimize their influence on data equipment and manpower.

3.3.1.2.3 Technical;

- Civil construction of building;
- Relationships between process plant and interacting processes
- Pipe, cable and duct routing;
- Accommodation for future expansion.

3.3.1.2.4 Additional Factors;

- Accessibility, access control and security;
- Public relations, emergency preparedness and viewing areas.

3.3.1.3 Defining Task Zones in the Control Room

Task Zones within a control room must be clearly defined in order to design parameters in and around the area effectively. Typically, the area required for the control of Unit One i.e. console, storage, work area, floor space and lighting etc. must be designed as a combined entity in order to clearly define the Task Zone. In defining the task zones the following guide shall be used

- Identification of the task zone e.g. Unit 1 control console, printer station etc.
- Number of users per zone including the variability in the number for both normal & abnormal operating conditions;
- Estimated sizes of fully equipped consoles & work area per zone and their estimated spaces requirements;

- Requirements for admin functions & shift handovers;
- Team meetings & briefings etc.

3.3.1.4 Design of the Layout of the Control Room

The functional design of the control room should be based on an overview of the task zones and the requirements of each of these task zones. The functional design must take into cognisance the following aspects:

- Tasks requiring links and the frequency thereof;
- Ease of access to/between the task zones;
- Overall architectural layout of the building such as columns, shape, traffic & service passages;
- Environmental constraints (for example: windows in relation to computer screens, emergency exits etc.);
- Visibility to plant if necessary;
- Accessibility from plant (for example ramp access for disabled people);
- Emergency operating considerations;
- Cooperation of operational personnel;
- Supervisor overview of the control room;
- Space per task;
- Links between task zones;
- Workstation/console requirements;

3.3.1.5 Communication

The concept of control room communication covers all interactions between an operator and other members of the operating team, meaning management, other console operators, and field operators. Consequently, control room design should address communication issues from this same broad perspective. Two very effective resources for supporting this broad perspective are a thorough communication analysis and the input from a carefully selected design team.

Communication analysis is a detailed study of how an operator interacts with the rest of the operating team in which the communications links between team members are established.

Areas that indirectly influence communication also are taken into consideration. During such an analysis, the following points should be considered:

- Types and location of communication devices, such as telephones, two-way radios or intercoms. These devices should be located so that they do not disturb other operators;
- Location of operators in relation to each other. Operators who normally need to communicate with each other should be placed close together to eliminate the need to talk across the room and disturb other operators;
- Role of team members in relation to the operator. Members of the operating team must have a clear understanding of each other's activities. Having defined roles enables team members to react quickly to abnormal situations;
- Optimal team size. The number of people required to respond to abnormal situations determines the size;

- Required lines of sight between control operators. Operators often need to see other control and field operators to facilitate verbal communication. However, an array of multi-tiered consoles often makes this impossible. Therefore, consoles should be arranged such that operators have an unobstructed view of each other;
- The organization's moral, social, and behavioral values result from its employees' beliefs, attitudes, and priorities. This becomes the organization's "corporate culture" and these values and beliefs affect communication between members of the operating team and help teach new employees how to operate effectively in their job. For example, if a control operator develops a "mentor" relationship with a trainee, the trainee may naturally emulate the control operator's work habits (which are, hopefully, good work habits);
- Task zones of individuals requiring frequent verbal communication with each other should be located close to each other;
- Control suite equipment should be located such that visual contact between operations is possible where and when needed;
- Communications that are not applicable or relevant to the control room function, should not distracted personnel;
- Rooms and locations with different functions should be physically separated to avoid sources of disturbance;
- Noise suppression such as ceiling material and wall mounted fabric shall be considered in order to prevent reverberating noise.

3.3.1.6 Traffic and Routing

Generally, movement in and around the control room by fellow operating staff does not create disturbance to the control room staff however the following aspects must be considered:

- Distances should be minimized;
- Access to peripheral areas such as the kitchen and ablutions should not transgress any operational zones;
- If there is a need to directly and visually monitor a certain part of a site, the workplace for this monitoring task determines the location of the control room on the site;
- Any restriction placed on access for unauthorised personnel should not impede access for authorised personnel;
- Special consideration should be given to undesirable walking routes, such as short cuts using emergency exits. The layout of the control room should be such as to permit easy access to all areas that might legitimately need to be visited;
- Users may feel uncomfortable sitting with their backs to an entrance or frequently used walkways. It should also be possible, from a normal position, for the operator to observe persons entering a room with minimum distraction.
- The use of glass partitioning should be carefully reviewed to avoid creating a "gold fish bowl" environment.

3.3.1.7 Entrances and Exits

The following must be considered:

- Where possible, the use of an airlock scenario shall be installed at the entrance to the control room;

- Doors and passageways in the control room should enable access to and transport of most equipment;
- Ready access to first aid equipment, emergency equipment and emergency exits shall be considered.

3.3.1.8 Environmental Conditions

The following environmental factors should be considered:

- Materials used for floors, walls and ceiling should be such that glare, reflections and large contrasts are controlled. Where needed, noise should be minimized by appropriate means of using sound absorption material on the floor, wall and ceilings;
- Potential sources of disturbance should be identified and considered. The location of the control room should be planned in such a way that the impact of these disturbances is minimized;
- Location of the control room to minimize possible risk of exposure to hazards such as toxic materials, pollution and radiation is required where such hazards may be present.

3.3.1.9 Cleaning

The following should be considered:

- The use of durable building or construction materials, which require minimum cleaning and are easy to clean, is recommended;
- Adequate provision shall be allowed for socket outlets on none critical circuits for use of cleaning equipment;
- Provisions should be made to minimise dirt and contaminates in the control suite by means of a special walk off matt that can be removed periodically and cleaned;
- Storage and use of cleaning agents should not present a risk to personnel from fumes, contact or potential explosive atmospheres.

3.3.1.10 Maintenance

The following should be considered:

- It should be possible to perform maintenance with the minimum disturbance to the operation of the control suite;
- Equipment should be easily accessible for maintenance purposes for example lighting tubes, fire and gas detection systems, and climate control systems;
- Cabling, ventilation ducts and so on should be properly concealed, but easily accessible at all times for maintenance and repair. Possible future extensions of cabling should be taken into account.

3.3.1.11 Visitors

In designing an arrangement for a control room, accommodation should be made for visitors which include both public (external personnel) and professional (none control room Eskom staff such as process technicians and maintenance staff) visitors.

Aspects to be considered:

- Public visitors should be guided through the control suite in a way that minimizes potential distractions and disturbances. The operator's activities should not be affected by the presence of visitors. Facilities should be created for adequate reception of public visitors, for example outside the central control room;

- Facilities should be designed to accommodate the viewing of displays by professional visitors without unnecessary disturbances to the control room operators;
- Where confidential information is presented, it should not be possible to see this from the viewing areas;
- Viewing areas should be designed so that control room operators do not feel that they are there for “entertainment” of the visitors.

3.3.2 Supporting Information

Some of the information that operators and others require will be in document form, for example drawings, handbooks, manuals and electronic storage media.

The following provision should be made:

- The information should be stored and structured in such a way that information used frequently can be easily retrieved;
- Filing and storage facilities should be adequate for the anticipated volume of material;
- None core documentation should be housed in adjacent areas such as the supervisors office in order to avoid excessive storage requirements in the control room;
- Filling systems must be limited so that the area does not become a collection area for old paperwork;
- Special provision should be made for easy access to material that is required in emergency responses;
- In order to save space and speed up research, the use of computer assisted documentation should be considered, particularly for emergency procedures.

3.3.3 Functionally Related Rooms

3.3.3.1 Kitchen and Kitchenettes

The following aspects shall be considered as part of the control room layout:

- Kitchens should be located off the main control room;
- Adequate extraction shall be installed removing unpleasant odours from cooking;
- The kitchen shall be furnished with a microwave and a fridge as a minimum;
- Each operator shall be allocated a small lockable cupboard sufficient to store eating and drinking utensils;
- The kitchen shall be for the sole use of the control room staff and shall be located such that non-control room staff cannot have easy access.

3.3.3.2 Peripheral Amenities

The following aspects shall be considered as part of the control room layout:

- Permit to work (PTW) facilities;
- Emergency exits and equipment;
- Relaxation area;
- Smoking area with adequate ventilation;

- Personal storage area;
- Toilets, showers, washroom;
- First aid area/facilities;
- Conference room, meeting rooms, training and simulator areas;
- Technical support centre (commissioning facility and engineering work station);
- Areas for contractor personnel;
- Emergency room.

3.3.4 Operator console layout

The ultimate beneficiaries of a well-designed control room will be the control room operators and associated users. The guidelines documented in this section are intended to create a usable and working environment which is more consistent with modern operational demands, thereby resulting in a solution which minimizes error and enhances productivity.

3.3.4.1 Principles of Control Console Layout

Once the operational zones have been identified, grouping of control consoles should be based on functional linkages, for example, equipment and information sharing, direct lines of sight and requirements for direct speech.

Console layouts should take account of such functional links, as face to face communications and sightlines to shared information overview displays, as detailed in the project brief and the manpower and equipment matrix. Interpreting these functional layouts to possible room layouts is achieved by replacing functional groups with approximate workstation footprint sizes and adjusting the layouts to maintain the required circulation and the user objectives.

The following aspects should be considered when allocating the positions of consoles within the control room:

a. Architectural considerations;

- Entrances/exits;
- Personnel safety;
- Future expansion.

b. Operational consideration;

- Task analysis;
- Team working;
- Organisational factors;
- Consistency of design within the Eskom Group;
- Physically challenged.

3.3.4.1.2 Selection of control console space allocation

In particular the following factors have to be taken into account:

- The selection of space for a control room should be based on the usable area, not the gross area;

- Obstructions and structural features, such as pillars and awkward corners, within a proposed planned control area, will severely reduce the available space and could result in sub-optimal work layouts;
- Experience indicates a value for planning floor-space allocation is to allow for 9m² to 15m² per working position with a minimum of not less than 9m². This has been found to be satisfactory for rooms with more than one control room operator and which are permanently staffed, and takes account to typical equipment volumes, sitting space and maintenance access. Precise requirements may vary however, space requirements shall be based on the job assignments determined in the development of the design brief. This space provision shall be based on the use of the "usable" area;
- If additional staff is required to be accommodated during abnormal operations within the control room, sufficient space should be allowed for these additional staff to be practically accommodated;
- Square, circular and hexagonal spaces are preferred for the arrangement of functional groups, because they offer the potential of maximizing the number of interactive links, long narrow spaces should be avoided since they can unduly reduce options. It should be noted however, that hexagonal & circular configurations are likely to concentrate noise;
- Space provision should consider requirements over the full planned life-span of the control room and account should be taken of future increases in workloads, staffing and equipment. Life-span of control rooms are typically in the order of 15 years, therefore an additional space allocation of 25% be allowed.

3.3.4.1.3 Positioning

When considering alternative ways of positioning out a number of control consoles the following factors should be taken into consideration:

- Whether control consoles are dedicated to individual operators or are shared;
- Whether each control console is identical;
- Whether all operations can be carried out from a single control console or tasks are spread amongst a number of consoles;
- Where a number of control rooms, operating on the same system, are located on various sites, they should adopt similar layouts. Adopting this approach facilitates the transfer of control personnel from one site to another and can reduce training time and errors;
- Control console arrangements shall take into account operation under normal and abnormal modes of system operation;
- Where ventilation systems, light fitting and windows have already been installed, positioning of control workstation should take account of these to avoid draughts, glare and reflections on visual display screen;
- Social contact within the control room should be allowed for by grouping operators so that informal conversations (those which have nothing to do with the operation of the control room) can occur between individuals without compromising operator efficiency. In large control room, particularly care should be taken that such informal links can be maintained when staffing levels are reduced during quieter periods;
- Control console layouts should provide an operationally satisfactory working environment under both maximum and minimum staffing levels;

- Control console layouts should provide for the convenient storage and display of all necessary reference documentation which control room operators require to access as part of their duties as well as items which can be required in emergency conditions;
- Where control consoles are grouped together the minimum distance between adjacent consoles should not result in individuals sitting within each other's "intimate zones". Whilst occasional close working may be acceptable, working positions adopted for extended periods should avoid control room operators having to intrude within each other's intimate zones;
- Spacing between control room operators should take account of shared equipment, where consideration of common reach zones or potential problems of interference due to noise need to be applied;
- Approximate control workstation sizing for initial layout purposes should take account of such factors as equipment size, flat worktop provision and the requirements for non-workstation storage and accommodation for workers with disabilities;
- When selecting room layouts, attention should be paid to training requirements for control room operators, for example, additional space for equipment adjacent to a normal operator's position or a separate, discrete training workstation;
- Layouts should take account of maintenance requirements and access spaces for technicians and equipment removal, particularly where this involves bulky items;
- The general arrangement of control consoles should be such that flow from general circulation areas is inhibited. However, the use of actual physical barriers to do this is not advocated;
- Control workstations should be positioned such that views of entrances and exits are minimised to reduce visual distraction from the normal operating position unless operational requirements demand this.

3.3.4.1.4 Additional Consideration Parameters

The following should be considered:

- The layout of control console should take account of future requirements. Control room console layout should take account of the initial operation as well as the requirements likely to be in place at the end of the planned life span. Such consideration should include the most likely upgrades in terms of equipment, additional working positions and changes in operational procedures;
- The need of those with disabilities should be considered during the layout of the control room by, for example, allowing additional circulation spaces and introducing ramps for wheelchair access;
- Hard-copy information storage should be classified such that the most appropriate provision can be made within the control room;
- Adequate provision should be made for the storage of items of a personal nature, both in the control room, at the control workstation (briefcases, purse) or outside the control room area on locker rooms (for clothing etc.);
- The requirements of the secondary users, as such field operators, who sometimes need to work in the control room on a temporary basis should be considered. This can sometimes involve the provision of suitable worktops to lay out paper work, appropriate seating and accommodation for coats and helmets. All such requirements should be fully determined by the conduct of an appropriate task analysis.

3.3.4.1.5 Posture variation

The following should be considered:

- There are ergonomic benefits in varying postures during periods of work, typically at 8 – 12 hour shifts. Thus the control console layouts and work functions should allow control room operational staff to change their posture at the control console and move from their console from time to time, hence the requirement for a breakaway zone. This zone can be classified as a simple table and chair that is away from the console however close proximity must be retained providing a general overview of the console. Under no circumstances should this breakaway zone be in isolation from the operational console thereby facilitating the primary control duties to be undertaken as part of a time-critical activity;
- The selection of chairs for the operators forms a critical element to the overall design. A chair must be designed for 24/7 usage and shall typically cater for 4 posture variations namely, bent forward, erect, reclined & relaxed. The chair must offer adequate back and neck support and must move freely on suitable castors between either ends of the control console.

3.3.4.2 Supervisory Control Console

Supervisory control consoles should take full account of the additional reference material which is sometimes required to be stored, display and used at these positions.

In arranging supervisory control workstation layouts, an early decision needs to be taken as to whether the primary duties of the supervisory are to supervise the systems, the control room operators or both. For system monitoring, layouts will place greater priority on equipment positioning, whereas for direct operator supervision, workstation positioning in the room and workstation profiles are more important.

Layouts should allow for additional circulation around supervisory positions and the temporary accommodation of visitors.

3.3.4.3 Monitors and Visual Display Units

Sufficient monitors must be positioned on the console in order for the operator to perform his function effectively. It is strongly recommended that operational visual display units requiring interaction between the operator and the process are positioned collectively. It is recommended that operational displays are split between closely located monitors (typically 19”) and remotely located larger monitors (typically 42” and above).

3.3.4.3.1 Large Screen Displays

The literature and empirical results agree that an “overview function” is the most important for large screen displays in control rooms. This means the function of actual performing operations on the large screen displays is not primary. Large screen displays provide mostly shared and mostly permanent source of information and are viewable for everyone inside the control room. Even managers visiting the control room interact mostly via the large screen displays instead smaller operator workstations.

This tends to enhance teamwork and collaboration between the occupants of the control room in monitoring and executing abnormal operations. Shared monitoring of different units by operators is possible when employing large screen displays. It has been observed that situation awareness and shared plant behaviour are high on control rooms with large screen displays.

The large screen display is, because of its size and purpose, often placed at a distance from the operators’ work stations, which then distinguishes it from the ordinary desktop displays at the operator desk. As modern computerised control rooms bring more and more heavy demands on human performance, which lead to increased cognitive workload, the design of the display area is of high importance in trying to reduce the cognitive workload.

To meet the general functions of operators, unit shift supervisors and supporting staff, large screen displays are required in all unit control rooms in Eskom. Proposals not to employ large screen displays must be well justified and clearly show how loss of the large display functionality is mitigated.

Consideration must also be given to the skills level and experience of the operating staff, where certain level of detail in the mimics is not useful to expert and experienced operators. The design of large screen display should consider the following factors: -

a) Pattern recognition via analogue elements, visual patterns and cues vs digital numbers

b) Permanent source of information vs a changing operating display

c) Status mimic vs layout mimic showing process layout. The latter is valuable to newer and inexperienced operators, as it can be also be used as a learning tool. Whereas a status mimic suits more the experienced operator, where in time, the operator gets to know by location the status of main plant auxiliaries and parameters, without bothering about the plant layout (as this is already known).

d) Incorporating permanent view of Critical Alarms vs the scrolling alarms in workstations

e) As part of an Operating design, a procedure on standardising on a set of mimics during plant monitoring can be finalised by each power station to improve monitoring and shift handover.

The following requirements concern the location of shared visual displays within the control room. Many differing technologies can be used for overview visual displays, including banks of monitors, projected displays, hard-wired mimics and static maps/diagrams. When designing control room layout for these differing solutions, the constraint imposed by the various solutions will need to be considered. Such constraints include limitations on viewing angle, contracts ratios and image construction.

Where common or general information visual displays are required to be used on a regular or continuous basis, the preferred position is directly in front of the control room operator such that it can easily be seen when looking over the operating console or can be scanned by eye-movement alone.

For very large visual displays, which need to be monitored on a continual or regular basis, it is recommended that the control room operators be allocated sections of the common displays which they can affectively and conveniently monitor.

Where information on large overview visual displays is required to be regularly used by control room operators, the design of the visual displays and the layout of the control room should ensure that all the information which needs to be used by a control room operator can be seen from the normal working position for both the vertical and horizontal planes.

Necessary information presented on shared overview visual displays shall be visible by personnel, with applicable 5^{th} to 95^{th} percentile body dimensions of the user population, from their normal working positions.

3.3.4.3.2 Essential Instrument display

The placement and layout of the essential measurement visual displays, as required by the Fossil Fuel Firing Regulations (FFFR) section 4.14, shall be designed in such a manner so that all information is clearly visible and legible from the operator's normal working position. This view is seen as where the information presented on a common or general shared visual display does not have to be read whilst operating the console, or provides secondary information. Hence the displays can sometimes be mounted to one side of the control workstation. Such displays should be positioned so that all information required can be reliably read from the control room operator's normal position, by simple rotation of the control chair.

3.3.4.3.3 General Location Parameters of VDU's

The following points shall be considered:

- Windows should not be located adjacent to visual displays or within the same field of view;
- Artificial room lightning should not interfere with the visibility of any section of the visual display units;
- Finishes around off-workstation, shared visual displays should be carefully controlled so as not to interfere with the visibility of parts of the shared visual display;
- Entrances and exits should not be located within the same field of view as major off-workstation visual displays;
- When grouping visual displays at the console or locating larger displays off the console, a rear screen shall be installed in order to prevent distraction from movement directly behind the monitors.

3.3.5 Control Room Finishes

3.3.5.1 Lighting

Effective use of lighting arrangements in a control room environment forms a critical aspect of the overall success of the design. Two aspects of lighting design must be considered during the room design process, namely:

- Light intensity and practicality;
- Decorative lighting contributing to the ambiance of the environment.

Where decorative ambiance lighting is used, colours and intensity shall be carefully considered so that its appearance is not in strong contrast to the interior lighting. Decorative lighting shall have the option to dim the light intensity or to be turned-off.

Statutory regulations, SANS 10114-2, Interior Lighting, Part 1: Artificial Lighting, stipulate that indoor control rooms in an electricity generating station shall be a minimum of 400 lx and computer rooms shall be a minimum of 630 lx.

In the modern control room environment of combining computers and process control systems, it is recommended that light intensity at the operator control console is designed to meet the minimum of 630 lux.

3.3.5.1.2 Control console lighting

Due to the high light intensity of achieving 630 lx at the control console it is critical that flexibility is incorporated into the design. Although 630 lx is the prescribed legal minimum it should be noted that few operators will ever function comfortably at this level. Flexibility can be achieved at the console by providing the operator with dimmable lighting circuits or the incorporation of a console mounted task light. The individual operator must be provided with the facility to adjust the light intensity at the console. Where this facility is proved to be inadequate, the operator will resort to adjusting the intensity by removing globes or starters from installed lights.

3.3.5.1.3 Task zone lighting

During the design process of the control room the task zones have been identified such as the operational zone around a console, admin area and printer station etc. In order to enhance and further define these areas, lighting design forms a critical element. The use of down lighters is recommended to achieve this goal.

3.3.5.1.4 Control room lighting

The general lighting in the control room shall be designed with flexibility in order to easily adjust the intensity levels uniformly per circuit throughout the control room. This shall be achieved by the incorporation of assigning several individual circuits, varying the lamp wattage ratings, selecting a combination of light fittings and introducing dimmable circuits.

3.3.5.1.5 Positioning of lights

It is critically important that selection of the light fitting and the positioning thereof does not create a bright “strip” of luminance viewable by any of the control room personnel seated at their normal position of work. The use of bulkheads is strongly advocated in order to hide the position of fluorescent tubes thereby indirectly creating a washed luminance rather than stark direct luminance.

Task zone lighting shall be positioned such that it forms a direct beam of light directly in or around the perimeter of the zone. Positioning of such lights should take into consideration reflection on VDU’s and equally, the effect of creating shadow lines by operators working in the bent forward position.

3.3.5.1.6 Emergency lighting

Circuits and light intensities shall be designed such that control room staffs are able to perform their function of operating during periods of lighting supplied from the essential supply. A best case scenario would be for the emergency lighting and normal lighting to be the same, so that there is minimal additional stress on the operating staff.

For instances of complete power failures, sufficient luminance shall be sustained in order to adequately operate the plant under emergency conditions. This lighting shall be provided for sufficient time to allow for the complete safe shutdown of the plant. This time must be determined during the design phase, and cater for the worst case scenario as determined by the various plant systems. As per statutory requirements, traffic routes and exits shall be adequately illuminated to facilitate evacuation of the area. Where the location is being used for Emergency Preparedness requirements, the lighting shall further meet such specific needs.

3.3.5.2 Heating Ventilation and Air Conditioning (HVAC)

3.3.5.2.1 Introduction

Non-effective air conditioning systems are often found to be the biggest singular source of discomfort to the control room staff. Although individual parameters of thermal comfort will vary from person to person the air conditioning system must be designed such that it provides the following parameters:

- Reliability;
- Cooling and heating;
- Humidity control;
- Adequate air circulation;
- Air filtration and pressurisation;
- Sufficient fresh air;
- Adjustability.

Combined with the above, it is critically important that the system complies with the following:

- Air diffusion shall not cause excessive drafts;
- The HVAC system shall not create disturbing noise.

Air conditioning systems shall be designed such that varying ambient temperatures between day/night and summer/winter shall not adversely affect the performance of the system.

3.3.5.2.2 Parameters of control room air conditioning

The following parameters shall be used for the design of air conditioning systems in control rooms:

- Air temperature: 22ºC +/- 1.5 ºC
- Humidity: controlled between 40 - 60%
- Air changes: minimum of 8 room volumes air changed per hour
- Air speed: 0.25 - 0.5 m per second
- Fresh air make-up: 20%

3.3.5.2.3 Server rooms

Dedicated server rooms are often located adjacent to the main control room which generally double up as the engineering work station although occupancy of the room is on an ad-hoc basis. The control room air conditioning system should not be shared with server room as the control room air conditioning system is primarily designed for the comfort of the operating personnel and not intended to cool electronic equipment.

Dedicated air conditioners shall be installed for the server room to cool the PC's and other electronic equipment as per 240-56355731: Environmental Conditions for Process Control Equipment Used at Power Stations Standard. Special attention must be drawn to the heat loading capacity of the PC's during design and an allowance of 25% over design of heat dissipation must be allowed for.

The installation of individual split units for additional cooling or standby purposes is not advocated due to the inherent problems of facilitating drainage away from the server room.

3.3.5.2.4 Equipment rooms

Equipment rooms are generally unmanned areas containing a vast array of termination cabinets and control system equipment. The HVAC system required for the equipment room shall be separated completely from the control room HVAC system.

3.3.5.2.5 Dust and pollutants

The design of the control room HVAC system shall allow for slight over pressurisation in order to prevent dust ingress. Where possible, the entrance to a control room shall be through an air lock thereby reducing dust ingress.

Fresh air make up shall pass through an adequate filtering system that can be easily maintained. Equally, the fresh air intake point shall be located away from any gaseous and dust sources.

3.3.5.2.6 Peripheral amenities

Areas such as toilets, smoke rooms and kitchens shall be maintained at a lower pressure than the main control room in order to avoid any odour ingress. Each peripheral area shall be fitted with individual extraction venting to atmosphere. Smoke rooms specifically, require an air supply and extraction system of 20 l/s per m².

3.3.5.2.7 Acoustic Environment

The ambient noise in a control room should not exceed a level of 45 dB. Background noise levels should not be greater than 35 dB. Auditory alarms should be approximately 10 dB above the

background sound spectrum of the control room in order to be audible, and less than 15 dB higher than the background to avoid startling staff and effecting speech communication.

In order to achieve these parameters the control room must primarily be located away from noisy machinery. Internally within the control room, the use of acoustic absorbing ceiling tiles shall be used. Additional acoustic absorbance can be achieved by means of vinyl type floor coverings and the use of material clad wall fixtures.

As more people and more consoles occupy the control room, the level of noise increases, which can impacts operator productivity. The challenge to control room designers is to provide an acoustical environment that promotes communication and productivity, while reducing conversational distractions and uncontrolled noise overall noise. The relationship between noise and its negative impact on people conclude that noise from background conversations is the most disruptive source of noise.

Conversational noise from other operators poses a constant distraction and may lead to a loss in productivity. In addition, uncontrolled noise from printers, HVAC equipment, and radios or other two-way communication devices also contribute to the operator's loss of attention. The use of the following four types of design elements can reduce noise levels and improve worker efficiency:

- Acoustical ceiling systems;
- Carpet or vinyl type floor coverings;
- Sound masking;
- Furniture type and placement of acoustical panels.

3.3.5.3 Furniture

Materials used for the construction of furniture within the control room must be of a durable nature to withstand the usage requirement of continuous 24 hour operation. Materials selected must comply with the Eskom corporate standards (see section 2.2). For example, Maple must be used for wooden furniture construction. The edges and trims of furniture must be such that there are no sharp edges susceptible to damage from inadvertent knocks. Where wooden furniture rests directly on the ground, aluminium skirting shall be installed and sealed to prevent damage from cleaning fluids and equipment.

Work surfaces shall be scratch and heat resistant and of such material as to facilitate ease of cleaning. Metal work surfaces, either coated or polished shall not be permitted.

Work surfaces on the control consoles shall be manufactured from Corian which provides a mouldable, non-porous surface that is warm to the touch. Note, the functionality of an optical mouse on the Corian surface, or any other surface material, must be verified during the selection process prior to construction.

3.3.5.4 Ceiling Features

The use of bulkheads within the control room is strongly advised. Bulkheads provide the ability to define task zones by means of shape, lighting and colour contrasts.

The use of domed features built over an operational zone shall not be permitted due to the whisper effect caused by the parabolic shape. Domed bulkheads are only permitted as decorative features however; their use must be limited to areas outside of the operational zones.

3.3.5.5 General Ambiance

The general ambiance of the control room must be in accordance with the Eskom corporate identity. Examples of control room designed based on these principles are attached in ***Appendix F*** for reference and use. However, in order not to overpower the occupant's, subtle use of the corporate identity colours is promoted. In all other areas, neutral colours shall be used. Paint shall be of such a quality as to allow frequent wiping and cleaning.

3.4 RESPONSIBILITY

For projects to be executed, this guideline must be included and referenced to in the Stakeholder Requirements Document. The LDE will be responsible to ensure that the process defined within the guideline is followed and that the minimum requirements and deliverables identified are complied with.

3.5 RECORDS

The results of all the questionnaires, feasibility studies, design and engineering deliverables etc. should be kept until any major changes are done to the control suites. On completion of the project, these records can be used for the post mortem analysis of the final control suite designs to verify compliance to the URS and intent of the guideline.

4. AUTHORISATION

This document has been seen and accepted by:

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5. REVISIONS

Date	Rev.	Compiler	Remarks
September 2013	0	Lendl Govender	Document created from 36-456.
May 2014	0.1	Lendl Govender	Draft document for Review
June 2014	1	Lendl Govender	Final Document for Authorisation and Publication
September 2017	1.1	Christoph Kohlmeyer	Updated Draft after Comments Review Process
September 2017	2	Christoph Kohlmeyer	Final Rev 2 Document for Authorisation and Publication

6. DEVELOPMENT TEAM

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

- Farhaad Jooma - C&I Engineer Komati Power Station
- Sonja Basson - C&I CoE HMI & Control Room Ergonomics
- Charles Kigozi - C&I Engineer Ingula Power Station
- Christoph Kohlmeyer - C&I CoE Plant Engineering

7. ACKNOWLEDGEMENTS

J.F. Viljoen is the original compiler and developer of this document in the form of 36-456.

APPENDIX A: CONCEPTUALIZATION OF THE CONTROL ROOM UPGRADES

Eskom Generation	SITE SURVEY QUESTIONNAIRE	

Title: **Conceptualization of the Control Room Upgrades**

Applicable Power Station:

Date of Survey:

Revision:

Total No of pages:

Review Team members:

COMPILED BY	ACCEPTED BY	AUTHORISED BY
.....	.....	.....

1. INTRODUCTION

The purpose of this questionnaire is to determine how you feel about the physical work environment of your control room.

Please note:

- The following questions are for external analytic purposes only.
- They will not be used to try to identify any individual.
- Please answer all the questions. Think carefully before the answer them.
- However, if you feel uncomfortable about answering any then do not do so.

2. HOW THIS SURVEY WORKS

- This survey consists of statements made about your working environment.
- Next to each statement is a rating scale as shown below. Please respond to each statement by checking the appropriate box with a cross (X) according to your own honest opinion.

Example

"I can comfortably see and use every display screen from one fixed seating position."

- If you disagree with the statement and cannot comfortably see and use every display screen from one fixed sitting position, then select either **-3, -2, or -1** depending on how strongly you disagree.
- Select **0** only if you do not have strong feelings *for* or *against* the statement.
- If you agree with the statement and you can comfortably see and use every display screen from one fixed sitting position, then select either **3, 2, or 1** depending on how strongly you agree.
- If the statement is not relevant to you, select the **Score** (not/applicable) box.

-3	-2	-1	0	1	2	3	Score
Very Strongly Disagree	Strongly Disagree	Slightly Disagree	Neutral	Slightly Agree	Strongly Agree	Very Strongly Agree	Average Score
			X				

3. EMPLOYEE BACKGROUND

a. How long have you worked in this Control Room?

Less than one year	
One year to less than two years	
Two years to less than five years	
Five years to less than ten years	
Ten years or more	

b. What is your age?

Under 21	
21 to 34	
35 to 44	
45 to 54	
55 or older.	

c. What is your gender?

Male	
Female	

d. Which of the following best describes your role in the organisation?

First-level supervisor	
Manager/supervisor higher than first level (including senior management positions)	
Not a manager or supervisor	

4. WORK ENVIRONMENT

-3	-2	-1	0	1	2	3	Score
Very Strongly Disagree	**Strongly Disagree**	**Slightly Disagree**	**Neutral**	**Slightly Agree**	**Strongly Agree**	**Very Strongly agree**	**Average Score**

1	Controls	-3	-2	-1	0	1	2	3	Score
1.1	I can comfortably see, reach, and operate every control from one position.								
1.2	I never have to leave my work area to attend to controls on back panels during operational sequences in which continuous monitoring or the timing of control actions may be critical.								
2	**Visual Displays**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
2.1	I can comfortably see and use every display screen from one fixed sitting position.								
2.2	From my fixed seating position at my console, I have full view of all control and display panels (including alarm displays) in the main control room that I need to see.								
2.3	I never have to strain my eyes to clearly see the contents of a display screen.								
2.4	I never have to twist my body or neck for extended periods of time in order to operate a								

	control or view a display screen.								
2.5	I often use the large overhead display screen as a source of information.								
3	**Work Station Space**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
3.1	There is sufficient space at my console for tasks requiring reading or writing.								
3.2	My work area is never cluttered with unnecessary objects.								
3.3	There is never food or other personal belongings that clutter my work area which might interfere with control room operations.								
4	**Seating**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
4.1	My chair is easy to adjust to various positions.								
4.2	My chair rolls and moves freely.								
4.3	My chair offers sufficient legroom at the console.								
4.5	My dedicated console chair is always available.								

-3	-2	-1	0	1	2	3	Score
Very Strongly Disagree	**Strongly Disagree**	**Slightly Disagree**	**Neutral**	**Slightly Agree**	**Strongly Agree**	**Very Strongly agree**	**Average Score**

5	**Communication**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
5.1	It is physically easy to have good visual and voice contact with my shift supervisor.								
5.2	I can easily communicate vocally from my seat at my console to any other relevant personnel.								
6	**Movement Around the Control Console**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
6.1	I have adequate space to take up my position at my console.								
6.2	During normal operation, I have adequate space to move around within								

	my work area.								
6.3	During emergency operations, I have adequate space to move around within my work area.								
7	**Documentation**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
7.1	All procedures and other documents that may be needed for ready reference are easy to locate and extract for use.								
8	**Emergency Equipment**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
8.1	In the event of an emergency, all personal protective equipment is easily and readily accessible.								
8.2	All emergency equipment is clearly marked and accessible.								
9	**Personal Belongings**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
9.1	There is a suitable and secure place where I can keep my food.								
9.2	There is a suitable and secure place where I can keep my bag, rain-coat, etc…								

-3	-2	-1	0	1	2	3	Score
Very Strongly Disagree	**Strongly Disagree**	**Slightly Disagree**	**Neutral**	**Slightly Agree**	**Strongly Agree**	**Very Strongly agree**	**Average Score**

10	**Bathrooms**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
10.1	The bathrooms are tidy and clean.								
10.2	The bathrooms are adequate, practically located, and easily accessible.								
10.3	In the event of an emergency, I can easily be contacted in the bathroom by co-workers.								
11	**Kitchen/Eating Area**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
11.1	The kitchen/eating-area is tidy and clean.								
11.2	The kitchen serves my needs and requirements.								

11.3	The kitchen/eating-area is practically located, and easily accessible.								
11.4	In the event of an emergency, I can easily be contacted in the kitchen by co-workers.								
12	**Relaxation Area**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
12.1	I make use of an area, separate from my control console, where I can relax.								
12.2	This relaxation area serves my needs and requirements.								
12.3	This relaxation area is, practically located, and easily accessible.								
12.4	In the event of an emergency, I can easily be contacted in the relaxation area by co-workers.								
13	**Thermal Comfort**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
13.1	The control room temperature is comfortable throughout the entire control room during the day.								
13.2	The control room temperature is comfortable throughout the entire control room at night.								
13.4	The air in the control room is fresh.								
13.5	There are no distractive ventilation drafts in the control room.								

-3	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
Very Strongly Disagree	**Strongly Disagree**	**Slightly Disagree**	**Neutral**	**Slightly Agree**	**Strongly Agree**	**Very Strongly agree**	**Average Score**

14	**Lighting**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
14.1	The lighting at my console is satisfactory for me to perform all my tasks.								
14.2	I can control the lighting at my console to suit my needs.								
14.3	There is no need to ever adjust the lighting at my console.								
14.4	The lighting in the control room is satisfactory for me to perform all my other tasks around the control room.								

14.5	When monitoring a visual display, I am not distracted by glare or reflectance.								
15	**Auditory Environment**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
15.1	During normal operations, I am never distracted by unwanted noises from inside or outside the control room.								
15.2	During emergency operations, I am never distracted by unwanted noises from inside or outside the control room.								
15.3	During normal operations, I can always clearly hear auditory signals.								
15.4	During emergency operations, I can always clearly hear auditory signals.								
15.5	Verbal communication is never strained due to background noise.								
15.6	During normal operations, I am never distracted by the movement of co-workers through my work area.								
15.7	During emergency operations, I am never distracted by the movement of co-workers through my work area.								

-3	-2	-1	0	1	2	3	Score
Very Strongly Disagree	**Strongly Disagree**	**Slightly Disagree**	**Neutral**	**Slightly Agree**	**Strongly Agree**	**Very Strongly agree**	**Average Score**

16	**Ambience**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
16.1	The current control room décor (carpeting, wall colour, decorative lighting) helps to create a pleasant and positive working environment in the control room.								
17	**General**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**Score**
17.1	I am proud of my physical work environment.								
17.2	My physical work environment gives me a strong sense of personal satisfaction in performing my job.								
17.3	My workplace is well maintained.								
17.4	I would recommend employment to a friend due to the condition of the physical								

	work environment.								
17.5	My company places high importance on the state of my physical work environment.								
17.6	From what I've heard or seen, my physical working environment is superior to that of other control room working environments in other companies.								
17.7	I have not applied for another job due to the state of my physical work environment. (In the past six months)								
17.8	My physical work environment motivates me to maintain very high standards of quality in performing my tasks.								
17.9	My physical work environment stimulates teamwork and close-cooperation between my co-workers.								
17.10	The condition of my physical work environment has never encouraged me to be absent from work.								

5. GENERAL COMMENTS

What would you most like to change about your physical work environment?

Any other comments:

Thank you for your time!

6. ANALYSIS OF DATA

Each answer has been assigned a weighted value. In order to calculate the average score, the total weighted value is summed and divided by the number of answers received.

From experience, it has been determined that an average score of 0.75 or below is unacceptable for a control room environment, and corrective actions will definitely be required in the final solution.

APPENDIX B: EQUIPMENT AND MANPOWER MATRIX

Eskom Generation	SITE SURVEY QUESTIONNAIRE	

Title: **Equipment and Manpower Matrix**

Applicable Power Station:

Date of Survey:

Revision:

Total No of pages:

Review Team members:

COMPILED BY	ACCEPTED BY	AUTHORISED BY
.....	.....	.....

	DESIGNATION	TERMINOLOGY	LOCATION (% of time)			DCS EQUIPMENT					MISC	ESKOM NETWORK					ADDITIONAL COMMENTS
No			Control Rm	Own Office	Outside Plant	PC's	Monitors 19"	Keyboard	Mouse	Printer	Lever Arch Files	PC's	Monitors 19"	Keyboard	Mouse	Printer	
1	Power Plant Master																
2	Unit No 1 Console Operator																
3	Unit No 2 Console Operator																
4	Unit No 3 Console Operator																
5	Unit No 4 Console Operator																
6	Unit No 5 Console Operator																
7	Unit No 6 Console Operator																
8	EOD/SER Console Operator																
9	EOD HV Yard Operator																
10	Engineering Work Station																
	SOUTH SIDE PLANT OFFICE																
11	Unit 1-2-3 Senior Appointed Sup																
12	Senior Plant Operator 1																
13	Senior Plant Operator 2																
14	Senior Plant Operator 3																
15	Commissioning / Outage Desk																
	NORTH SIDE PLANT OFFICE																
16	Unit 4-5-6 Senior Appointed Sup																
17	Senior Plant Operator 4																
18	Senior Plant Operator 5																
19	Senior Plant Operator 6																
20	Commissioning / Outage Desk																

	DESIGNATION	TERMINOLOGY	LOCATION (% of time)			DCS EQUIPMENT					MISC	ESKOM NETWORK					ADDITIONAL COMMENTS
No			Control Rm	Adjacent	Outside Plant	PC's	Monitors 19"	Keyboard	Mouse	Printer	Lever Arch Files	PC's	Monitors 19"	Keyboard	Mouse	Printer	
1	WTP Shift Manager																
2	WTP Console Operator																
3	WTP Outside Operator 1																
4	WTP Outside Operator 2																
5	Engineering Work Station																
6																	
7																	
8																	
9																	
11																	
10																	
12																	
13																	
14																	

	DESIGNATION	TERMINOLOGY	LOCATION (% of time)			DCS EQUIPMENT					MISC	ESKOM NETWORK					ADDITIONAL COMMENTS
No			Control Rm	Adjacent	Outside Plant	PC's	Monitors 19"	Keyboard	Mouse	Printer	Lever Arch Files	PC's	Monitors 19"	Keyboard	Mouse	Printer	
1	Slurry Plant Shift Manager																
2	Slurry Plant Console Operator																
3	Slurry Plant Outside Operator 1																
4	Slurry Plant Outside Operator 2																
5	Engineering Work Station																
6																	
7																	
8																	
9																	
11																	
10																	
12																	
13																	
14																	

APPENDIX C: TYPICAL CONCEPTUAL DESIGN RESPONSIBILITY

Eskom Generation	**SITE SURVEY QUESTIONNAIRE**	

Title: **Conceptual Design Responsibility and Delivery Matrix**

Applicable Power Station:

Date of Survey:

Revision:

Total No of pages:

Review Team members:

COMPILED BY	ACCEPTED BY	AUTHORISED BY
.....	.....	.....

CONCEPTUAL DESIGN RESPONSIBILITY & CHECK LIST MATRIX

Project Title:		**Revision**	**0**
Project Number:		**Date**	
Project Location:			
Contractor Project Manager:		**P= Primary Responsibility**	
Client Project Manager:		**S= Support**	

		CONCEPTUAL DESIGN RESPONSIBILITY		CONCEPTUAL DESIGN CHECK LIST		
ITEM	**DESCRIPTION**	**Eskom**	**Contractor**	**Eskom**	**Contractor**	**COMMENTS**
A	**PROJECT SCOPE DEFINITION**					
	Clarification of design scope					
	Clarification of the project team					
	Review & incorporation of applicable standards					
	Operator Site Survey					
	Notes Measurements Drawings & Photo Survey					
	Manpower & Equipment Matrix					
	Identification & clarification of HMI interface					
	Areas of review for the conceptual design as per guidelines doc					
B	**PRELIMINARY CONCEPTUAL DESIGN DELIVERABLES**					
	General Arrangement Drawing of the control room layout					
	Clarification of design Constraints					
	Verification of the equipment & manpower matrix					
	Compilation of the operator site survey highlighting areas of concern					
	Clarification of Standards used					
	Clarification of philosophies used for the design					
	Indication of the functional areas (task zones) and interactive links					
	Space allocations to task zones					
	Indication of natural lines of traffic movement					
	Work station layout					
	Displays, monitors and control system equipment allocation					
	Supervision philosophy					
	General Arrangement Drawing of the peripheral amenities					
	Indication of proposed finishes & materials					
	Indication of Corporate Branding Identity elements					
C	**FINAL CONCEPTUAL DESIGN DELIVERABLES**					
	Narrative document					
	Equipment & manpower matrix					
	Dimensioned General Arrangement Drawing of the control room layout					
	Dimensioned General Arrangement Drawing of the peripheral amenities					
	Floor plan general arrangement drawing					
	Ceiling plan general arrangement indicating bulkheads & HVAC locations					
	Small power, UPS and communication socket outlets					
	Preliminary UPS power requirement calculations (ind on above drawing)					
	Lighting layout indicating circuits and typical light fittings					
	Preliminary lux level calculations (ind on above drawing)					
	Layout and dimensioned control desk drawing					
	3 Dimensional graphical representation of the control room (2 views)					
	Definition of Standards used					
	Detailed traffic movement drawing					
	Provisional material finishes board					
	Provisional Budgetary Estimate					

APPENDIX D: TYPICAL DETAIL DESIGN RESPONSIBILITY

Eskom Generation	SITE SURVEY QUESTIONNAIRE	

Title: **Detail Responsibility and Check List Matrix**

Applicable Power Station:

Date of Survey:

Revision:

Total No of pages:

Review Team members:

COMPILED BY	ACCEPTED BY	AUTHORISED BY
.....	.....	.....

DETAILED DESIGN RESPONSIBILITY & CHECK LIST MATRIX

Project Title:		**Revision**	**0**
Project Number:		**Date**	
Project Location:			
Contractor Project Manager:		**P= Primary Responsibility**	
Client Project Manager:		**S= Support**	

		DETAILED DESIGN RESPONSIBILITY		DETAILED DESIGN CHECK LIST		
ITEM	**DESCRIPTION**	**Eskom**	**Contractor**	**Eskom**	**Contractor**	**COMMENTS**
A	**PROJECT SCOPE DEFINITION**					
	Clarification of detailed design scope					
	Clarification of the project team					
	Review & incorporation of applicable standards					
	Review of Conceptual Design Package					
	Review of Manpower & Equipment Matrix					
	Clarification of HMI and control systems interface					
B	**DETAILED DESIGN DELIVERABLES**					
	Dimensioned Sections & Elevations of General Arrangement Drawing of the control room layout					
	Dimensioned Sections & Elevations of General Arrangement Drawing of the peripheral areas					
	Detailed architectural drawings inc equipment specifications					
	Detailed structural drawings					
	Detailed floor plan c/w equipment specifications					
	Detailed ceiling plan c/w equipment specifications					
	Detailed furniture drawings inc filing, storage and worksurface details					
	HVAC circulation drawings and specifications					
	Detailed lighting layout drawing and equipment specifications					
	Detailed lighting single line drawing					
	Lux level calculation sheet					
	Detailed small power layout drawing					
	Small power single line drawing					
	Detailed control console layout drawing indicating viewing angles, distances and material specifications					
	Control console cable layout drawing					
	General cable layout drawing					
	Cable schedule					
	Termination details					
	Detailed Corporate Branding Identity elements					
	Material finishes specifications					
	Detailed Budgetary Estimate for the supply & installation					
	Detailed project execution plan					
	Detailed project schedule					

APPENDIX E: TYPICAL IMPLEMENATION RESPONSIBILITY MATRIX

Typical Implementation Responsibility Matrix

Eskom Generation	SITE SURVEY QUESTIONNAIRE	

Title: **Implementation Responsibility Matrix**

Applicable Power Station:

Date of Survey:

Revision:

Total No of pages:

Review Team members:

COMPILED BY	ACCEPTED BY	AUTHORISED BY
.....	.....	.....

ESKOM POWER STATION CONTROL SUITE RESPONSIBILITY MATRIX (EXAMPLE)

Project Title:
Project Number:
Project Location:

Ilitha Project Manager:
Client Project Manager:

REVISION No:
DATE:

ITEM No	DESCRIPTION	CONTRACTOR A	CONTRACTOR B	CONTRACTOR C	ESKOM	CIVIL CONTRACTOR	COMMENTS
A	**BUILDING WORK**						
	Ceiling, excluding the bulkhead						
	Walls, brickwork & final finish including painting						
	Floor finish to control room & PPMCO office, excluding matts & rubber tiles						
	Floor finish for raised section						
B	**DETAILED ENGINEERING REQUIREMENTS**						
	Detailed Design of small power Distribution Board						
	Detailed Design of Lighting Distribution Board						
	Supply to small power DB						
	Supplies to lighting DB						
	Supply & installation of small power DB						
	Supply & installation of lighting DB						
C	**MISCALLANEOUS**						
	Design, supply & install of kitchen extraction inc electrical						
	Design, supply & installation of smoke room extraction inc electrical						
	Supply and install water supply & drain point for kitchen						
	Supply & install server rack unit						
1	**KITCHEN, Supply & Install**						
1,1	Kitchen Cupboards inc. sink & tap						
1,2	Kitchen Bench Seat						
1,3	Kitchen Table						
1,4	Kitchen Chairs						
1,5	Fridge						
1,6	Hydroboil						
1,7	Waste Bin						
1,8	Microwave bracket						
1,9	Microwave						
1.10	Roller Towel bracket						
2	**SMOKE ROOM**						
2,1	Smoke room bench seat						
2,2	Smoke room chairs no castors						
2,2	Waste Bin						
2,3	Ashtrays						
2,4	Maple Cladding to wall						
3	**CONTROL ROOM**						
3,1	Fabric Cladding to walls						
3,2	White Boards						
3,3	Filling & Storage unit						
3,4	Printer Station						
3,5	Viewing Station Shelf						
3,6	Breakaway Table						
3,7	Operator Chairs Executive)						
3,8	Breakaway Chairs on castors						
3,9	Rubber interlocking tiles						
3.10	Waste paper bins						
3,11	Waste bin						
3,12	Misc in / out trays etc						
4	**CONSOLES**						
4,1	3 Base Control Consoles						
4,2	Filling units at consoles						
4,3	Electrical / Inst Distribution inc Fans						
4,4	Electrical & data communications connections to consoles						
5	**WAITING ROOM**						
5,1	Waiting room bench seat						
5,2	Walkoff matt						
5,3	Waste paper bin						
5,4	Frosted Vinyl décor to glass						
5,5	Framed image (glass covering)						
6	**PPMCO OFFICE**						
6,1	PTW Counter with roller shutter						
6,2	Work table & desk						
6,3	Filling & Storage cabinet						
6,4	A2 Hanging File unit						
6,5	Modular Key / Padlock unit						
6,6	Work table & desk						
6,7	Executive chair						
6,8	Meeting table chair						
7	**BULKHEADS**						
7,1	Manufacture of bulkheads						
7,2	Onsite installation						
8	**LIGHTING**						
8,1	Supply of lighting units for the area (excluding DB)						
8,2	Installation of lights						
9	**SMALL POWER RETICULATION**						
9,1	Supply power skirting and socket outlets						
9,2	Installation of socket outlets & power skirting						

APPENDIX F: CORPORATE IDENTITY REQUIREMENTS

Due to the fact that the control rooms provide a window into the Power Station business, Generation places great emphasis on achieving a visual style that demonstrates both an elegant and professional overall effect. Utmost care must therefore be taken during implementation to make sure that no single component diminishes the total style, while still ensuring good ergonomic practice is maintained.

The visual style employed must conform to the Eskom Corporate Identity Requirements, which is governed by the Corporate Identity Policy. To ensure that these requirements are consistently applied at all Generation's control rooms, they have been specifically captured in this Annexure F.

The objective of this section is to provide guidance on achieving a consistent visual impression across all of Generation's power stations, which embodies the Corporate Identity Requirements to such an extent that any visitor to any control room can immediately identify the Eskom Brand. The rooms will not be identical as station-specific constraints must be catered for. However, overall impressions should be consistent.

The basic requirements are as follows;

1. FURNITURE

1.1 CHAIRS

The covering of all the chairs, and the arms and legs of the chairs shall comply with Eskom Corporate Identity Manual.

1.2 TABLES

The colour and finish of all tables and its legs shall comply with Eskom Corporate Identity Manual.

1.3 OPERATOR'S CONTROL DESKS

It is recommended that the control desk work surface is a hard solid surface material like Corian (Black Quartz colour recommended). Control Desks shall comply with Eskom Corporate Identity Manual.

1.4 OTHER

Other furniture such as printer stands, pedestals, drawer units etc. shall be similar to the rest of the main furniture in the control room.

2. ARCHITECTURAL FINISHES

2.1 WALL COVERINGS

Walls will be covered with acoustic panelling (Framed panels consisting of backing board, covered with high density foam and covered with fabric according to Corporate Identity requirements. It is recommended to use the Eskom Gold fabric.

In areas where acoustic panelling is not specified (e.g. at emergency exit, plain walls etc.) either they can be painted used according to Corporate Identity requirements, or light maple wood panelling must be used. This panelling can use a "Changing grain" principle to improve the visual effect.

2.2 FLOOR COVERINGS

The floors should have a grey/beige colour to match with the overall colour basis of the room. The floor colour should not be completely plain, but have a varying effect to reduce the impact of dirt. A hard-wearing, sound-deadening floor material such as Linoleum (e.g. Marmoleum or ESD Polyflor) should be used. This has antistatic properties which is also advisable when using computer equipment. There is a range of colours, it is easy to match later, and is very hard wearing. The product can be used as sheeting for large spaces, or cut to fit onto computer flooring. If required, inlays can be made with different colours to create a pattern on the floor.

It is strongly advised against using ceramic tiles in the control room. They are very noisy, uneven, and difficult to match later, and show the dirt more easily.

To define the operator's workspace more clearly, darker overlays can be positioned around the operator's desk. This overlay will typically be charcoal black, to minimise wear and tear and dirt appearance. The overlays can be removed for cleaning, and easily replaced later. The overlays must have a bevelled edge to reduce unevenness for chair castors.

2.3 CEILING

The ceiling will generally be white using suspended acoustic boards/tiles. Where required by the design, bulkheads will be constructed, and coloured white in general. Where specific bulkheads have been provided above the operators to define their workspace, these will typically be painted the Eskom Blue - Pantone 287.

2.4 PAINTING

Any general painting shall be done with colours from the following range;

Plascon Colour Expressions
- E14 – 2 (Hudson)
- E14 – 3 (Papyrus)
- E14 – 4 (Mayan Stone)
- E14 – 5 (Sombrero)
- Y1-C2-3 (Pale Linen)
- Y2-D2-3 (Veldrift)
- Y2-D2-2 (Stone Wash)
- Y2-D2-1(Waxen Tint)

Where required for painting of highlights, Plascon Emeralda blue or any paint that matches Eskom's blue – Pantone 287 can be used. This is only to be used as an accent colour in very small amounts. White can typically be used for the ceilings. See Summary of Corporate Identity Manual, 240-103414344, for more details.

2.5 STAIR RAILS AND OTHER METALWORK

All metalwork shall be powder coated in Eskom cowrie gold. If wooden rails are used they must be maple.

2.6 GLASS

Glass panelling (e.g. for supervisor offices, visitors areas etc.) will be 25% tint with colour to complement cowrie gold metal frame finishes. Sandblasted look dècals can be used to provide signage, and provide restricted viewing for privacy on some panels.

2.7 DOORS

Where doors are made of glass panels, they must conform to section 2.6 above. If the doors are painted, they must comply with Eskom Corporate Identity paint colours in section 2.4 above. If the door has a wood finish, it must be maple. Door frames must be painted according to the Corporate Identity requirements.

3. FACILITIES

3.1 KITCHEN (LINKED TO CONTROL ROOM)

The finish of these facilities should tone in visually with the rest of the control room. Appropriate flooring and wall finishes for the applications shall be used. Colours should be consistent with Corporate Identity requirements – e.g. paint, glass, blinds, doors etc. Cupboards should use the same wooden finish as those in the control rooms.

3.2 SMOKING ROOM (LINKED TO CONTROL ROOM)

The finish of these facilities should tone in visually with the rest of the control room. Appropriate flooring and wall finishes for the application shall be used. Colours should be consistent with Corporate Identity requirements – e.g. paint, glass, blinds, doors etc. Furniture and Cupboards should use the same materials as those in the control rooms.

3.3 CUPBOARDS ETC. IN CONTROL ROOM

All built in lockers/cupboards etc. if they have a wood finish must be maple. Exposed areas (e.g. above cupboards) which have a wood finish must be clad in maple. The "changing grain" principle can be used to add effect. If not a wood finish, they must comply with the corporate paint colours.

3.4 TOILET / WASHROOM FACILITIES (LINKED TO CONTROL ROOM)

The finish if these facilities should tone in visually with the rest of the control room. Appropriate flooring and wall finishes for the applications shall be used. Colours should be consistent with Corporate Identity requirements – e.g. paint, glass, blinds, doors etc.

4. ACCESSORIES

4.1 CURTAINS

It is not envisaged that curtains will be used in the control rooms as they increase the dust loading, however if they are, they should match the upholstery material that has been used.

4.2 BLINDS

If blinds are required, they must be in the same colour as the wall coverings or it can be the same blue as the upholstery material.

4.3 NOTICE BOARDS

Frames for Notice Boards/posters/awards/paintings, etc. should have narrow frames. Ensure that the colour of the frame matches the Eskom Pantone swatch 8004 (Eskom gold) as closely as possible. If powder coated, use Cowrie Gold.

5. SIGNAGE

All signage in the area (equipment lables, nametags, room lables etc.) must comply with the Corporate Identity Policy.

5.1 OFFICE ACCESSORIES

Any accessories in the room (dustbins, potplant holders etc.) should comply to Corporate Identity Policy requirements i.e. matches the Eskom Pantone swatch 8004 (Eskom gold) as closely as possible. If powder coated, use Cowrie Gold.

6. GENERAL

6.1 FABRICS

Fabric to be used on chairs, screens etc. should be consistent with the specifications in the current Corporate Identity Policy.

6.2 POWDER COATING OF METAL PRODUCTS

Where powder coating of metallic components is required, the colour should be similar to Akzo Nobel. Range: Interpon 600 Matt, ANP 9054, cowrie gold

6.3 OTHER FITTINGS

Provision for LAN cabling and electrical reticulation in the control room, will need to be made. Typically a multi-tier power/communication/data skirting around the outside boundary walls of the room must be provided. This should be coloured to match the selected wall paint colour, or Eskom Pantone swatch 8004 or cowrie gold.

6.4 PROCUREMENT

When purchasing material with similar specification from different suppliers, the risk exists that differences exist due to different batches or grains. For this reason it is important that the same supplier is used wherever possible.

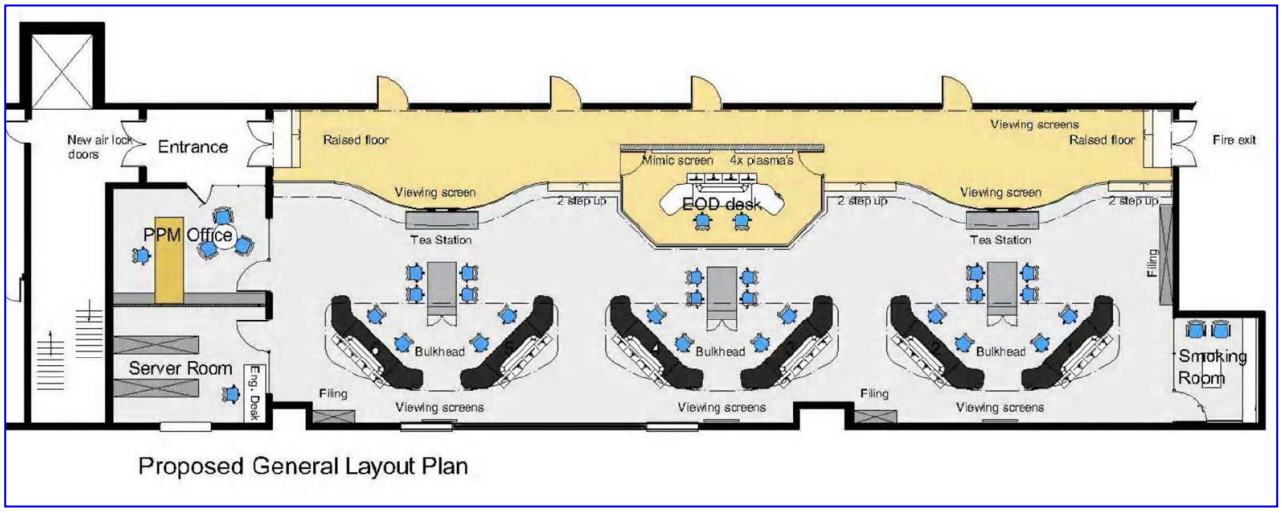
6.5 FLEXIBILITY OF IMPLEMENTATION

Flexibility is achieved by using a single colour floor throughout the room and creating functional spaces with contrasting colour overlays. Wrong initial positioning of desks etc. (current risk due to 2-phased implementation in refurbished control rooms) can thus be better accommodated with using different/contrasting inlays cut into the floor. Similarly, by making use of plastered board bulkheads that are painted the desired colour, the colour can be easily adjusted if required and fabric-covered acoustic panelling against the walls can be re-covered later.

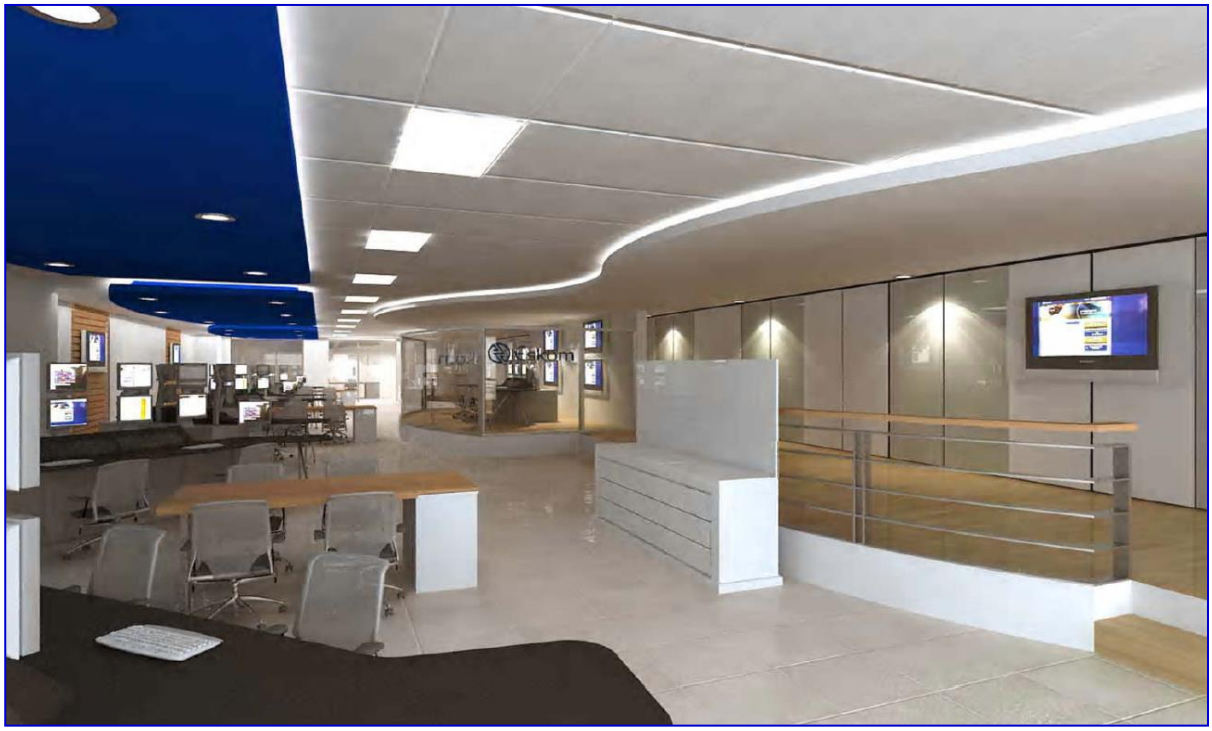
7. TYPICAL EXAMPLES OF CONTROL SUITE LAYOUTS

Below are a few examples of control room concepts that have been developed following the use of this Guideline. In practice, actual site constraints sometimes results in minor differences to this design, however the fundamental intent of providing a properly designed, ergonomically suitable control room should be the priority. Once constructed, it is very costly and difficult to make changes.

7.1 MATLA POWER STATION UNIT 1-6 AND EOD CONCEPTUAL DESIGN LAYOUT (AS PER THE STATION FEASIBILITY STUDY IN 2006)



Proposed General Layout Plan



Matla control room 3D overview

Matla control room 3D overview

7.2 GROOTVLEI POWER STATION UNIT 1-6 AND EOD CONCEPTUAL DESIGN LAYOUT (AS PER THE CONTRACTORS PROPOSAL IN 2006)

Grootvlei control room 3D Concept overview

Grootvlei control room 3D Concept overview

7.3 KOMATI POWER STATION UNIT 1-9 AND EOD CONCEPTUAL DESIGN LAYOUT

Komati control room 3D concept overview

7.4 KENDAL POWER STATION WATER TREATMENT PLANT CONCEPTUAL DESIGN LAYOUT