A Method for Reviewing Human Factors in Control Centre Design

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Introduction and User Information

Introduction

In recent years the development of new control room solutions in the Norwegian petroleum industry has resulted in increased performance demands on the control room operators. Typical trends in this development are:

- New functions and tasks are allocated to the control room, such as: radio communication functions, transport, surveillance and marine operations.
- Technological changes lead to increased amounts of information and more complex interfaces.
- New display and control technologies challenge traditional concepts of independence and separation of process control and emergency functions.
- The complexity of modified control rooms evolve beyond original design goals and requirements. This results from changes in operational scope, including control of peripheral (subsea) units, remote operation of installations, etc.
- Process output is increasing towards the limit of design specifications. This leads to increased demand on response time, accuracy of systems and control room operators in order to avoid temporary shutdown periods.
- Increased focus on cost saving is leading to reductions in number of control room operators.

The Norwegian Petroleum Directorate (NPD) has experienced that these changes clearly affect safety and the working environment related to control rooms for offshore installations. Lack of an integrated human factors perspective is often the main reason why designs fail to provide sufficient overview and support to control room operators.

In order to meet these challenges, the NPD has taken an initiative to develop this review method, which integrates relevant regulations, standards and principles of human centred control room design. The Institutt for energiteknikk (IFE) has developed this report for the NPD. A reference group of representatives from the operators have been involved in the development.

Development of the method is part of the NPD's strategy to ensure that the petroleum industry addresses human factors issues appropriately in control room design. Requirements relating to human factors issues in current government regulations and NORSOK standards are functional. More detail is given to the requirements related to physical work environment than presentation of information from safety systems, and there is a common misconception in the industry that by addressing ergonomics issues, human factors is also covered. In fact, the reverse is true, as ergonomics can be considered to be a part of the human factors discipline and not vice versa. Based on NPD's current experience from supervisory activities, it has become apparent that the industry would benefit from guidance on how to include human factors in the design process.

A new, international, 8-part standard on human factors in control rooms is currently being written (ISO 11064, Ergonomic Design of Control Centres). This review method has been written in line with the proposed content of Part 1 of that standard: Principles for the Design of Control Rooms, which is currently in a Final Draft form. Part 1 gives guidance on how to include human factors in the design process. Although some changes may be made to the final draft before it becomes an international standard, it is expected that the principles and substance will be much the same as the current version. In the future, it will probably form the basis for guidelines on human factors in control room development for offshore installations. It is neither the intention that this method should pre-empt the standard, nor is this method intended as a guideline for control room development. Such a guideline would necessarily be more detailed. The method is intended as a much needed design review tool that will harmonise with the future guideline, if and when it becomes available.

It should be stressed that this methodology does not introduce new requirements from the NPD. Although a new standard is referred to, the different steps of the design process are already covered by currently applicable regulations and standards.

This is a first edition of the report, which is being put out to get industry feedback before a revision that will be issued in 2001. This new revision will incorporate feedback from the industry, experiences from NPD's audits and the new set of government regulations due in January 2001.

Purpose

The purpose of this method is to review the design process to ensure that human factors principles and methods have been appropriately considered and integrated into control centre design in both new projects, and modifications and upgrades to installations on the Norwegian continental shelf.

Scope and Objectives

The scope of the review method covers control centres on installations involved in petroleum activities. When relevant, it should also be applied to control rooms on mobile installations, drilling units, and vessels used for manned underwater operations. These structures will be referred to collectively as installations for the purpose of this document.

The objective is to provide the operating companies with a practical and usable document, to assist them in evaluating whether human factors requirements, as set out in government regulations and recognised standards have been given appropriate consideration in the design of control centres on installations.

This method is aimed specifically at the human factors programme in control centre design, and does not cover general design issues.

Intended Users

The method is written for:

- the project leader, design team, equipment vendors, etc., to use during internal evaluation or reviews ; and
- external audits/reviews by either operators, contractor companies, equipment vendors or NPD.

The document can also be referred to by designers during the development process.

Overview of the Design Process

To establish a tool for development and verification of control centres, a suitable model for describing the development process is required. Figure 1 below, illustrates the main steps in the development process and is based on the content of ISO/DIS 11064 Part 1.

After the necessary management systems are identified and implemented and the design team is chosen, the design process is initiated. This process consists of five major phases: clarification of goals and requirements, analysis, conceptual design, detailed design, and operational feedback. Verifications are performed after the analysis, conceptual design and detailed design phases. The process is an iterative one where problems and discrepancies identified at the verification and validation stages are either resolved, or exceptions approved, before moving on to the next phase.

Phase A. Programme Management, Goals and Requirements

This phase covers the organisational and management aspects of the project.

Step 0: Human Factors Management

Guidance for human factors programme management is lacking in ISO/FDIS 11064-1 but has been included in the review process. This is to help operating companies who are not used to including human factors so formally in the design process. The review guidance examines the composition of the human factors team and the management of human factors issues relating to the design process. We have tried to follow the numbering system from ISO/FDIS 11064-1 in this document and as HF programme management is not covered in the standard this has been named Step 0.

Step 1: Goals and Requirements

This reviews the process of setting human factors goals and requirements for the project. The design documentation should show that an operational experience review, OER, has been conducted to identify human factors problems from previous or other similar designs. In addition, relevant regulatory requirements and standards related to human factors should have been identified before the goals and requirements of the project can be specified.

Phase B. Analysis and Definition

Once the goals and requirements have been specified, more detailed analyses are needed to determine more specific requirements.

Step 2: Functional Description

For a new control centre design, this phase will initially involve a detailed analysis of the functions of the control centre. For an upgrade, an analysis of the changes in functions of the control centre may be enough, assuming that a previous analysis has identified the overall control centre functions. This step reviews how the list of functions appropriate for the scope of the project was arrived at.

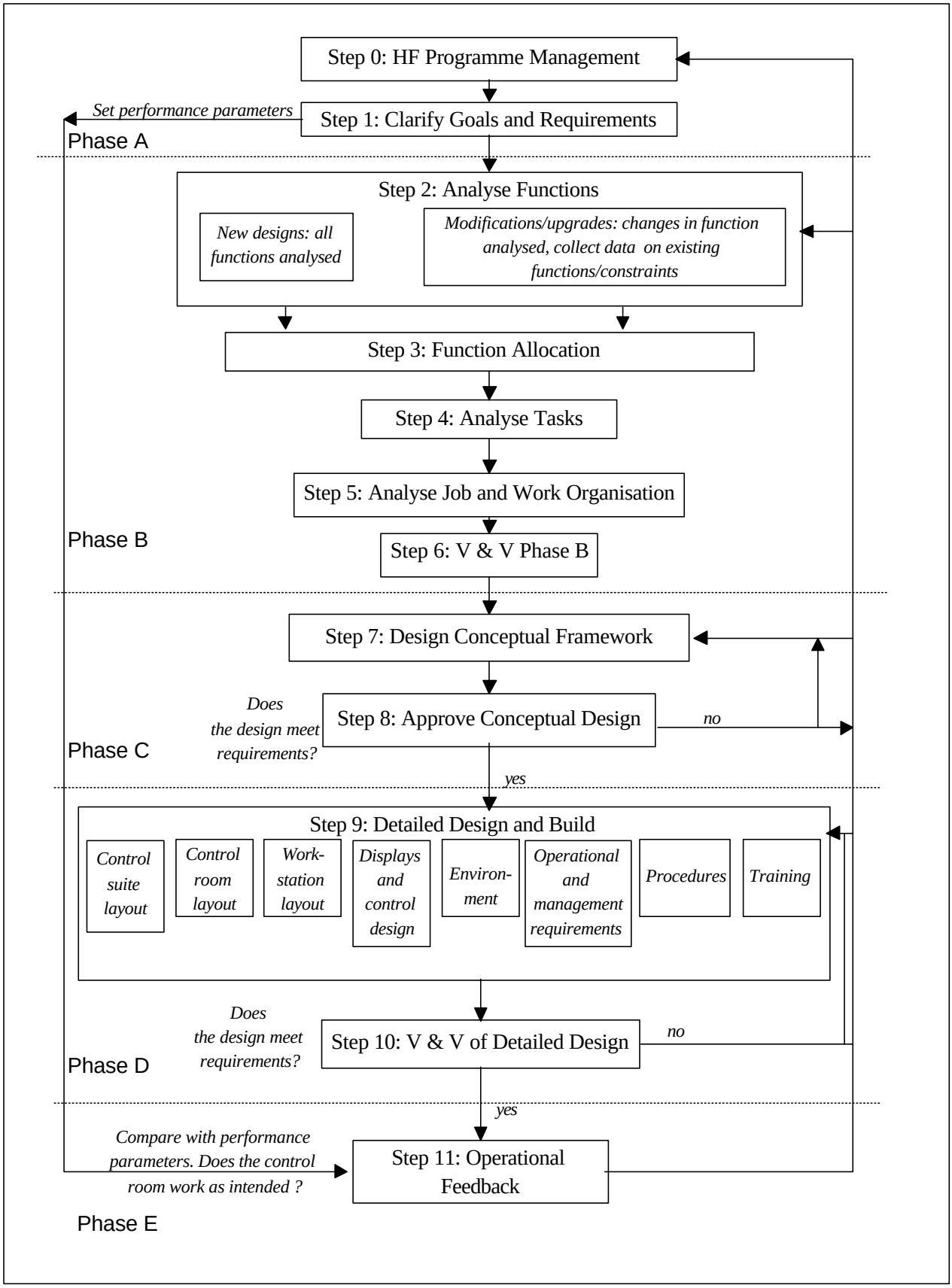
Step 0: HF Programme Management
Set performance parameters
Step 1: Clarify Goals and Requirements
Phase A
Step 2: Analyse Functions
New designs: all functions analysed
Modifications/upgrades: changes in function analysed, collect data on existing functions/constraints
Step 3: Function Allocation
Step 4: Analyse Tasks
Step 5: Analyse Job and Work Organisation
Phase B
Step 6: V & V Phase B
Step 7: Design Conceptual Framework
Does the design meet requirements?
Step 8: Approve Conceptual Design
no
Phase C
yes
Step 9: Detailed Design and Build
Control suite layout
Control room layout
Work-station layout
Displays and control design
Environ-ment
Operational and management requirements
Procedures
Training
Does the design meet requirements?
Step 10: V & V of Detailed Design
no
Phase D
yes
Compare with performance parameters. Does the control room work as intended ?
Step 11: Operational Feedback
Phase E

Figure 1: Control Centre Design and Modification Process

Step 3: Function Allocation

After a list of functions is drawn up they must be allocated to either central control room (CCR) operators or the automated systems. There is a constant tendency to base this allocation on what is possible for machines to do rather than what is best for the CCR operator. This step reviews the basis on which this allocation is made to ensure the operators' needs and abilities are taken into account in this process.

Step 4: Define Task Requirements

A list of CCR tasks that have been assigned to the CCR operators will be the result of Step 3. These must be analysed to determine what the operator needs, in terms of information, equipment, knowledge skills, etc., to carry them out. This step reviews whether the CCR operators needs have been properly analysed to ensure that the finished design is able to meet those needs.

Step 5: Job and Work Organisation

Individual tasks must be combined to make jobs. This step reviews the process of job design to ensure that individual operators have an optimal workload across all operational modes.

Step 6: Verification and Validation (V&V) of Phase B

An intermediate V&V is performed to check and approve as a whole the allocations and assignments made in the preceding steps of Phase B. The step reviews this checking process to ensure a safe and functional control centre will result and to ensure any conflicts between these preliminary design steps are resolved before carrying out the conceptual design.

Phase C. Conceptual Design

Step 7: Conceptual Design Framework for the Control Centre

After the analyses have been conducted, a control room conceptual design is developed. In the conceptual design, issues such as equipment selection, layout, traffic patterns, information flow, and space allocation are typically addressed. In both upgrades and new designs, models should be built to provide a tool for verification and validation, e.g., mock-ups, 3-D CAD, or Virtual Reality (VR) models. This step integrates the results of previous steps and produces one or several design concepts and preliminary specifications. The review examines this process to ensure that human factors issues are fully considered.

Step 8: Conceptual Design Approval

A formal review of the conceptual design is an opportunity for checking the proposed design before starting detailed design. It also allows the project team to agree a common way forward for the design. Thirdly, it lets management see the proposals and decide whether to

support them before committing major resources. Fourthly, it reduces the risk that the project team must make expensive changes later in the project.

The design team then, in co-operation with future control centre users, validates the design using techniques such as walk-throughs, talk-throughs, and link analysis. Problems identified at the conceptual design stage are generally easy and relatively inexpensive to remedy. Any changes should be verified before proceeding to the detailed design phase.

Phase D. Detailed Design

The detailed design phase is an iterative process that begins with identifying clear and detailed design requirements for systems, and ends with a working control room.

Step 9: Detailed Design Requirements

This step reviews the process of developing the detailed design specifications to ensure that the correct human factors input has been identified for the following detailed design areas:

1. Control Suite Arrangement;
2. Control Room Layout;
3. Workstations Layout and Dimensions;
4. Design of Displays and Controls;
5. Environmental Design;
6. Operational and Managerial Requirements;
7. Training; and
8. Procedures.

Step 10: Verification of the Detailed Design

This step is intended to verify that the design conforms to human factors principles. Throughout the detailed design phase, verifications are recommended to ensure that the human factors requirements are met. These evaluations should consist primarily of guidelines and standards-based reviews. Deviations are easier to correct early in the design process than later on. However, once the final design is chosen, scenario-based reviews must be conducted to ensure that the control centre's crew performance meets the acceptance criteria. At this stage, correcting deviations or problems in the design becomes more costly, and trade-offs will probably need to be made.

Phase E. Operational Feedback

Even though the design is implemented, the consideration of how human factors issues affect control room performance and working environment should not end here. Government regulations require that operational experience is systematically collected, analysed and used in improving safety and work environment. This step reviews the topics that should be covered to provide the basis for human factors improvements, as well as suggestions on methods that may be applied. Operational experiences provide useful feedback to designers

regarding the successes and problem areas of the design, and will offer necessary input to future design projects.

User Information

Organisation of Document

The document is divided into six parts: five that relate to the individual phases in the design process (see Figure 1 on page 8 for an overview of the phases and steps); and this, the user guide. The intention is that the relevant steps can be used independently at the appropriate stage in the design process. The user guide should be used with each step and contains a common references section and a common acronyms and abbreviation section to be used with the individual steps.

Organisation of Individual Steps

The user will find that there are different levels of detail between steps of the method. This is because it is unnecessary to repeat current standards that give adequate human factors guidance and that are routinely used in the design process. Where these are available, they are referred to. Areas where human factors support is lacking have been identified, and these are covered in more detail in the method.

Each step is divided up into sections. The Purpose, Introduction, Objectives, Regulatory Requirements and Other Standards and Guidance Sections are intended to remind the reviewer of what was intended when carrying out that step in the design process. The Sources of Information for the Reviewer and Review Guidance sections are more specifically directed at the review process itself.

Terminology

Terminology is the same as used in applicable government regulations and NORSOK standards, i.e:

- “Shall” indicates a requirement that must be followed in order to conform to regulations.
- “Should” indicates what is preferred but not necessarily required.
- “May” indicates what is permissible.
- “Can” indicates what is possibilities or capabilities.

Typography

In the individual steps the following conventions are used:

1. **Questions for review guidance are written in 12-point bold type.**

   Explanations and other support information are written in 11-point normal type.

Explicit links to regulations, applicable standards and other guidance are written in 11-point bold type.

1. Were appropriate human factors analyses conducted as part of the design process?

The type of analyses that are desirable will depend on the nature of the project and the scope of the work.

Note: the SAM Regulations, § 16 set requirements for systematic analyses to be carried out as a part of design work.

NORSOK S-002 § 4.9.4 sets requirements for an ergonomic job analysis to be carried out as a part of design work.

NORSOK S-002 § 4.9.5 sets requirements for a human-machine interface analysis to be carried out as a part of design work.

NORSOK S-002 Appendix I § I.3. refers to different types of analysis that can be used in this context.

Areas of Application

The method shall be used for the following situations in the way described below.

New Designs

New designs include the design of systems, equipment or facilities for control centres of new installations and new control centres on existing installations. When deciding the depth of the human factors evaluation, the design team should consider design standardisation, system complexity, consequences of human errors and effect on safety. **The application of a human factors evaluation to new designs shall be an integral part of the planning process and will include all steps in Phases A to E.**

Upgrades and Modifications to Existing Designs

This includes the design or modification of existing systems, equipment or facilities on installations. Existing control centres are likely to undergo gradual changes for a variety of reasons, such as:

- changes to regulatory requirements,
- ageing of existing systems,
- introduction of new technology,
- tie in of new wells, subsea installations,
- remote operation of installations,
- operating experiences.

The human factors work involved in smaller, evolutionary changes will be considerably different from a new control room and the most important human factors issues will depend on the nature of the modification. **The application of a human factors evaluation to modifications and upgrades shall be an integral part of the planning process and will involve all the steps in Phases A to E. However, the scope of each step will be limited to the systems, equipment and facilities to be changed in the new design and any others that will be affected by those changes.**

Very little practical guidance is available on human factors in upgrade projects. Some sources suggest that existing human factors information can sometimes be re-used. Arguments that the proposed changes are acceptable can be based on the degree of innovation versus the degree of similarity to previous designs, e.g., if functionality can be shown from existing documentation or if there are successful arguments showing that the change is similar to an existing system that has already qualified. These arguments can use existing data and help to reduce the amount of new human factors work needed. New human factors work should focus on areas of change and their integration with the existing system.

Audit of Existing Control Rooms

In the evaluation of existing control rooms, definitions and analyses have been made at a time when requirements may have been different to those currently in force. **Therefore, the analyses in Phase D and E only, will be applied when evaluating existing control rooms.** I.e., an evaluation of the current state of the control room will be performed.

Appendix A: Acronyms and Abbreviations

Abbreviations for Petroleum Industry Acts and Regulations

Abbreviation for Act or Regulations	Full Name of Act or Regulations
Emergency Preparedness Regulations	Regulations relating to emergency preparedness in the petroleum activities. Issued by the Norwegian Petroleum Directorate18 March 1992
Explosion and Fire Protection Regulations	Regulations relating to explosion and fire protection of installations in the petroleum activities. Issued by the Norwegian Petroleum Directorate 7 February 1992
Management Systems Regulations	Regulations relating to management systems for compliance with statutory requirements in relation to safety, working environment and protection of the external environment in the petroleum activities. Laid down by Royal Decree 27 June 1997
Petroleum Act	Act of 29 November 1996 No. 72 relating to petroleum activities
Safety and Communication System Regulations	Regulations relating to safety and communication systems on installations in the petroleum activities. Issued by the Norwegian Petroleum Directorate 7 February 1992
Safety Regulations	Regulations relating to safety in the petroleum activities. Laid down by Royal Decree 27 June 1997
SAM Regulations	Regulations relating to systematic follow-up of the working environment in the petroleum activities. Issued by the Norwegian Petroleum Directorate 8 March 1995
Working Environment Act	Act 4 February 1977 no 4 relating to worker protection and working environment, etc.

Definitions of Specialist Terms, Acronyms and Abbreviations

Term	Expansion
Accident	An event for which a barrier to unwanted energy flow or environmental condition fails, resulting in adverse consequences. Cf. Incident.
Action	The behaviour required to complete a task.
Alarm	An audible or visual annunciation resulting from a discrete change of state that requires an operator's attention.
Auxiliary shutdown facility, auxiliary shutdown room	An alternative location provided so that the plant normally controlled from the control centre can be shut down if the control centre becomes unavailable for some reason, such as an accident.
CCR	Central control room.
CCR Operator	Any member of staff who works in a central control room.
CER	Central equipment room.
Control centre	A combination of control rooms, control suites and control stations that are functionally related and all on the same site.
Control room	The core functional entity, and its associated physical structure, where operators are stationed to perform their allocated roles, including centralised control, monitoring and administrative responsibilities.
Control suite	A group of functionally related rooms located with the control room and including it, for example, rooms for supporting equipment and rest-areas for control room staff.
Design basis accident	A sequence of events, often identified by a probabilistic safety assessment, which is analysed in design work and that is considered an something within the scope of the design. Certain other accidents are considered 'beyond design basis.'
Design team	A multi-disciplinary group that is responsible for the planning, design, assessment and implementation of the design of the plant or installation and systems. A team responsible for designing a process or product, cf. review team.
Dimensioning accidental events	Accidental events that serve as the basis for layout, dimensioning and use of installations and the activity at large, in order to meet the defined risk acceptance criteria, cf. 'design basis' accidents. These events are defined by a risk analysis and can include blow-out, fire, explosion, collision, falling objects, etc.
Emergency control centre	A control centre provided to relieve the CCR and its staff from personnel traffic in a distress situation, usually located close to the CCR.
Emergency preparedness	All technical, operational and organisational measures that prevent a dangerous situation that has occurred from developing into an accidental event, or that prevent or reduce the harmful effects of accidental events that have occurred.
ESD	Emergency shutdown (system).

Term	Expansion
Function	An activity or role performed by a human or an automated system directed towards achieving a goal. A function may be decomposed into sub-functions, and is without a time sequence. A function is an activity, not the hardware that does it, nor the goal.
Function analysis	The decomposition of overall goals into functions and sub-functions. The purpose of a function analysis is to provide a basis for: function allocation to human or machine, job definition, workload assessment, the establishment of staffing, and the definition of essential information supporting the detailed design of the human-machine interface.
Goal	A production objective or safety objective.
Incident	An event for which a barrier to unwanted energy flow or environmental condition fails without loss or consequences. Cf. Accident.
Job	The full set of tasks assigned to a person or a group. Tasks making up a job are operationally related and are coherent concerning skill, knowledge and responsibility.
Job analysis	An analysis of the job definition to ensure that the job can be done.
Job definition	The allocation of tasks to a person or group.
Lesson Plan	A structured outline to be used by both instructor and trainee that contains learning objectives, an adequate amount of detail to ensure consistent training, and notes with respect to required support material, e.g., audiovisual equipment, overhead transparencies, tools, equipment.
LQ	Living quarters.
MCR	Maritime control room.
NORSOK	Norsk sokkels konkurranseposisjon [Norwegian offshore sector's competitive standing, an initiative to reduce cost on offshore projects].
NPD	Norwegian Petroleum Directorate.
Operating company	An entity that is granted a production licence pursuant to section 3-7 of the Petroleum Act that conducts the day-to-day management of activities on behalf of the licensees. (See Explosion and Fire Protection Regulations, where this entity is also referred to as the 'operator').
Operating mode	Normal operating modes include steady state operation, start-up, shut-down, isolation for maintenance, well testing, well intervention.
OS	Operator station.
PCS	Process control system(s).
Performance standards	Specific and measurable criteria that separate acceptable performance from unacceptable performance.
Plant mode	See operating mode.
PPE	Personal protective equipment, such as hard hats, gloves, ear-defenders, respirators.
Procedure	A functionally related time-sequence of tasks.

Term	Expansion
Recognised standards	Guidelines, standards, etc., that are internationally or nationally recognised within a specific professional field, and acts or regulations that are not directly applicable but that regulate corresponding or neighbouring industries and professional fields.
Review team	A team responsible for reviewing or auditing a process or product, cf. design team.
Safety functions (main)	Safety functions that need to be intact in order to ensure that personnel that are not directly and immediately exposed may reach a place of safety in an organised manner, either on the installation or through controlled evacuation.
SAS	The overall safety and automation system — monitoring, logic control and safeguarding of a plant. All such control equipment seen as a whole.
Simulator	A machine or computerised replica of any environment, device or process control system that is used for training or experimentation.
Task	Actions or collections of actions done to carry out a function.
Staffing	The number of operators required to run the control room and the knowledge and skills they need to possess to do it.
Job and work organisation	How tasks are distributed and organised among staff.
Task analysis	A detailed description of tasks. A systematic method for determining the tasks required in performing any particular job or function.
TER	Telecommunications equipment room.
Training, initial	The training, determined from task analysis, that is given to new or inexperienced personnel to enable them to perform specific jobs.
Training, refresher	The training, determined from task analysis, that is given to job incumbents that assists them to maintain the skills and knowledge needed to meet the requirements for successful job performance; this may be particularly important for tasks that are not frequently performed that but are critical, or for tasks that are difficult to perform.
Validation	Confirmation by examination and provision of objective evidence that the particular requirements for a specified intended use are fulfilled. In design and development; validation concerns the process of examining a product to determine conformity with user needs, i.e., does it do the job or not?
VDU	Visual display unit.
Verification	Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled, i.e., is it as we intended?
Warning	An alert to users of a potential hazard that could lead to health, safety or environment problems.
Work environment	The physical, chemical, biological, social and cultural factors surrounding a person in his or her work tasks.

Appendix B: References

Oil Industry Standards and Advisory Documents

NORSOK (1994) *Common Requirements Safety and Automation System (SAS).* Oslo: Norwegian Technology Standards Institution (I-002 Rev. 9 Aug. 1999; supersedes I–CR–002 Rev. 1, Dec. 1994).

NORSOK (1996a) *Control Centre.* Oslo: Norwegian Technology Standards Institution (I-CR-004, Rev. 1 Jan. 1996).

NORSOK (1996b) *Operational Principles.* Oslo: Norwegian Technology Standards Institution (O-DP-001, Rev. 1, April 1996).

NORSOK (1997a) *Living Quarters Area.* Oslo: Norwegian Technology Standards Institution (C-001, Rev. 2, Oct. 1997).

NORSOK (1997b) *Architectural Components and Equipment*. Oslo: Norwegian Technology Standards Institution (C-002, Rev. 2, Oct. 1997).

NORSOK (1997c) *Working Environment*. Oslo: Norwegian Technology Standards Institution (S-002, Rev. 3, Nov. 1997).

NORSOK (1997d) *General Area*. Oslo: Norwegian Technology Standards Institution (C-003, Rev. 1, Sep. 1997).

Norwegian Petroleum Directorate (1995) *Regulatory Supervisory Activities for Safety of Petroleum Activities on the Norwegian Continental Shelf.* NPD (YA–034).

Norwegian Petroleum Directorate (1997) *Regulations Relating to Management Systems for Compliance with Statutory Requirements in Relation to Safety, Working Environment and Protection of the External Environment in Petroleum Activities.* NPD (YA–018).

Norwegian Petroleum Directorate (1998a) *Maintenance Baseline Study: A Method for Self-assessment of Maintenance Management Systems.* NPD (Rev. 0, May 1st, 1998).

Norwegian Petroleum Directorate (1998b) *Orientation Concerning the Arrangement of Regulatory Supervision Relating to Safety and the Working Environment in the Petroleum Activities.* NPD (YA–036).

Norwegian Petroleum Directorate (1998c) *Regulations Relating to Implementation and Use of Risk Analysis in Petroleum Activities.* NPD (YA–049).

Norwegian Petroleum Directorate (1998d) *Regulations Relating to Explosion and Fire Protection of Installations in Petroleum Activities.* NPD (YA–057).

Norwegian Petroleum Directorate (1999a) *Guidelines to Regulations Relating to Emergency Preparedness in Petroleum Activities*. NPD (YA–054).

Norwegian Petroleum Directorate (1999b) *Regulations Relating to Safety and Communications Systems on Installations in Petroleum Activities.* NPD (YA–056).

Norwegian Petroleum Directorate (1999c) *Regulations Relating to Systematic Follow-up of the Working Environment in Petroleum Activities.* NPD (YA–060) ; supersedes 1995 version.

Norwegian Petroleum Directorate (1999d) *Regulations Relating to Safety in Petroleum Activities.* Laid down by Royal Decree 27th June, 1997 pursuant to Act 29, November, 1996 no. 72 relating to petroleum activities, sections 10–18. NPD.

Norwegian Petroleum Directorate (1993) Menneske-maskin forhold i kontrollrom: Ergonomiske analyser og retningslinjer.

Oljeindustriens Landsforening (1994) *Ergonomiske Retningslinjer for Sokkelindustrien [Ergonomic Guidelines for the Norwegian Continental Shelf Industry].* OLF (Rev. 033, May 1994).

Other Recognised Standards and Advisory Documents

Deutsches Institut für Normung (2000) *Terminology of Ergonomics.* Berlin: German Institute for Standardization.

International Atomic Energy Agency (1992) *The Role of Automation and Humans in Nuclear Power Plants.* Vienna: IAEA (IAEA–TECDOC–668).

International Atomic Energy Agency (1993) *Control Room Systems Design for Nuclear Power Plants.* Vienna: IAEA (IAEA–TECDOC–812).

International Electrotechnical Commission (1989) *Design for Control Rooms of Nuclear Power Plants.* Geneva: IEC (IEC 964 first edition 1989–03).

International Electrotechnical Commission (1995) *Nuclear Power Plants—Main Control Room—Verification and Validation of Design.* Geneva: IEC (IEC 1771 first edition 1995–12).

International Instrument Users' Associations (1998) *Ergonomics in Process Control Rooms Part 2: Design Guideline.* The Hague: International Instrument Users' Association WIB (M 2656 X 98).

International Standards Organisation (1999a) *Ergonomic Design of Control Centres — Part 1: Principles for the Design of Control Centres.* Geneva: ISO (Final Draft International Standard ISO/FDIS 11064–1).

International Standards Organisation (1999b) *Ergonomic Design of Control Centres — Part 2: Principles of Control Suite Arrangement.* Geneva: ISO (Draft International Standard 11064–2).

International Standards Organisation (1999c) *Ergonomic Design of Control Centres — Part 3: Control Room Layout.* Geneva: ISO (Final Draft International Standard 11064–3).

International Standards Organisation (1999d) *Ergonomic Design of Control Centres — Part 4: Workstations Layout and Dimensions.* Geneva: ISO (Working Draft 11064–4, version 1.1, 1997-7-30).

International Standards Organisation (1999e) *Ergonomic Design of Control Centres — Part 6: Environmental Requirements for Control Rooms.* ISO 11064–6. Not yet published.

U.S. Department of Energy (1992) *Writer's Guide for Technical Procedures.* U.S. Department of Energy. Washington DC, (DOE-STD-1029-92).

U.S. Nuclear Regulatory Commission (1993) Rev. 1, *Training Review Criteria and Procedures.* U. S. Nuclear Regulatory Commission, Washington, DC, (NUREG-1220).

U.S. Nuclear Regulatory Commission (1994) *Human Factors Engineering Program Review Model.* Ch 3: Element 2 — Operating Experience Review. Washington, DC: Division of Reactor Controls and Human Factors, Office of Nuclear Reactor Regulation, US Nuclear Regulatory Commission (NUREG–0711).

Canadian Atomic Energy Control Board (1995) *Human Factors Guides.* Atomic Energy Control Board, Ottawa, Canada. (INFO-0605)

Other References

Chartered Institution of Building Services Engineers (1994) *Code for Interior Lighting 1994.* London: The Chartered Institution of Building Services Engineers.

Creasy, R. (1980) Problem-solving the FAST way. *Proceedings of the SAVE (Society of Added Value Engineers) Conference,* pp. 173–175. Irving, Texas, USA: SAVE.

Higgins, J, and Nasta, K. (1997) *Human Factors Engineering (HFE) Insights for Advanced Reactors Based Upon Operating Experience.* Washington, DC: Division of Reactor Controls and Human Factors, Office of Nuclear Reactor Regulation, US Nuclear Regulatory Commission (NUREG/CR-6400).

Ingstad, O. and Bodsberg, L. (1990) *CRIOP: A Scenario-method for Evaluation of the Offshore Centrol Centre.*Trondheim: SINTEF (ISBN 82–595–5762–2).

Kirwan, B. and Ainsworth, L.K. (1992) *A Guide to Task Analysis.* London: Taylor & Francis.

Mager, R.F. (1984) *Preparing Instructional Objectives,* Revised Second Edition. Belmont, CA: Pitman Learning, Inc.

Monk, T.H. and Folkard, S. (1992) *Making Shiftwork Tolerable.* London: Taylor & Francis.

Patrick, J. (1992) *Training: Research and Practice.* Academic Press Ltd.

Price, H.E. (1985) *The allocation of functions in systems. Human Factors, 27(1),* 33–45.

Step 0: Human Factors Programme Management

Purpose

The purpose of this step is to ensure that human factors issues are given proper consideration when organising and managing the design process and that appropriate systems have been developed and implemented to do this.

Introduction

When designing a new control centre, or making modifications to an existing control centre, there needs to be a suitable team and process for carrying out the work. The team should include human factors expertise and there should be an appropriate plan for incorporating human factors issues in the design process.

A general problem at present is that CCR design teams consist mainly of people with control and instrumentation experience and with academic training in an engineering or similar technical discipline. In recent years, experienced operators and ergonomists have been included on the CCR design team, which allows valuable operational experience and working environment issues to be included in the design process. However, human factors expertise is still lacking in most cases and this results in an inadequate understanding of operators and the requirements placed on them by the control room environment. On the occasions that human factors help is used, it is generally to review the finished product, by which time it is too late, and too expensive, to have an impact on the design.

This step is aimed at ensuring an appropriate plan exists for human factors aspects of the design work and that management systems ensure human factors is considered when:

- reviewing the customer's objectives and requirements;
- seeking a common understanding/agreement of expected end-product with the client before contract signing;
- familiarising the team with the objectives and requirements for the project;
- formalising communication with the customer/client, including a plan for user experience input,
- integrating and interfacing the design work with other relevant project work if the control centre design is just a part of a greater design or modification task;
- carrying out and following up the design work as intended;
- identifying deviations from progress plan and design requirements, etc; and
- reporting, analysing and rectifying these deviations. Different procedures and systems can exist depending on type of deviations and who is to be involved in the deviation handling process.

Management of a human factors programme in control room design is, off course, an integrated part of the overall management of a project. Project organisation differs depending

on company policies and project requirements, and may also differ between phases within a specific design process. The guidance given here is intended to apply as generic guidance for a human factors programme. General project management is covered in other regulations and practices.

Objectives

- Ensure the CCR design team has the competence to achieve a design which satisfies internal and regulatory requirements relating to human factors
- Ensure that HF specialists are involved that have the necessary responsibility, authority, scope of work, communication and reporting lines and with a suitable organisation and budget to carry out the human factors design work
- Ensure that a proper plan is established which describes all the human factors activities intended to assist technical programme development
- Ensure that appropriate management systems for human factors are developed to achieve the planned result

Regulatory Requirements

The following regulations apply to this step:

- Working Environment Act, § 24
- Safety Regulations, §§ 11-13
- Management Systems Regulations, § 8 litera 1 and 2
- SAM Regulations, §§ 13 - 17 and § 25
- NORSOK S-002 §§ 4.1 and 4.2

Other Standards and Guidance

The following give additional guidance that is useful for this step:

- ISO/FDIS 11064-1 International Standards Organisation (1999a)
- TECDOC–812 International Atomic Energy Agency (1993)
- NUREG–0711 U.S. Nuclear Regulatory Commission (1994)
- INFO-0605 Atomic Energy Control Board of Canada (1995)

Information Sources for the Reviewer

- Regulatory requirements for management systems
- Company standards, policies and administrative controls relating to management systems
- Other standards and guidance used relating to the step
- Project planning documents
- Project management documents

Review Guidance

1. Did the CCR design team include appropriate Human Factors (HF) expertise and competence for the type of project?

The human factors expertise needed in the CCR design team will vary according to the scope of the project but should include human factors experts, ergonomists, and/or others with specific training in appropriate HF areas or methods, who together can carry out all the HF analysis and design work relevant to the scope of the project. HF subject matter experts may be called in as necessary for specific topics or areas of expertise, for example, to perform the analyses required in Phase B. This means that the people providing HF input to the CCR Design Team can change at different steps within the project. All those providing HF input during the life of the project are referred to as the HF specialists.

Note: the Management Systems Regulation § 8 litera 2e sets requirements for a description of manning and competence.

2. Were the HF specialists given an appropriate position in the organisation?

The specialists should have responsibility, authority and placement within the organisation to ensure that commitment to the work and aims of the project is achieved. If the HF specialists do not have sufficient authority, there may be successful resistance to change or to the use of time and resources on the work.

3. Were suitable workspace resources made available?

This refers to the resources, workspace and equipment required by the HF specialists to do the design work. There may be special equipment requirements, for example, the specialists should have appropriate office equipment, computer software, and space for mock-ups if these are included in the scope of the project.

4. Was training given in the use of the management system?

In order to ensure that the management system functions as intended for human factors, the HF specialists shall be trained in its principles, requirements and processes.

5. Was a system developed to keep the CCR design team updated on changes in all relevant rules, regulations and standards?

There shall be a description of the system for ensuring that all rules, regulations and standards relating to the project are current and that any changes in these are notified to the HF specialists and other members of the CCR design team, including consultants and vendors.

Note: the Management Systems Regulation § 8 litera 2b sets requirements for keeping relevant regulations up to date.

6. Was an HF leader identified for the HF specialists and his/her responsibilities, authorities, division of duties, communication and reporting lines clearly outlined?

Because of the possibility of HF specialists changing during the life of the project, including the possibility of calling in experts from outside the main CCR design team, a leader and co-ordinator is needed. The role of the HF leader shall be outlined and communicated to all other members of the CCR design team. It is essential that leaders understand their responsibilities within the design project in terms of:

- knowing the competencies required by external HF specialists to carry out the various analyses, design, verification and validation steps in the design process;
- scope and allocation of resources;
- ensuring the CCR design team know of the commitment to human factors;
- ensuring the HF programme is co-ordinated to produce the required results.

7. Were the roles of all other HF specialists clearly outlined?

The roles of the HF specialists shall be outlined and communicated to all other members of the project staff. This outlined shall include:

- responsibilities;
- authorities;
- division of duties;
- communication lines.

Roles and responsibilities should be clarified for the different HF specialists that may be called in during the life of the design project and especially emphasised in cases where the project organisations changes during the design project.

Note: the Management Systems Regulation § 8 litera 2d sets requirements for clarification of responsibilities, authorities and duties.

8. Were appropriate lines of reporting and communication developed?

The level at which communication takes place, both internally between HF specialists, and between the HF specialists and other CCR design team members, including client, consultants and vendors, shall be outlined. A documented process for interaction and information distribution should be developed. These communication lines should be two-way in order to:

- enable the HF specialists to communicate goals, requirements, discrepancies, etc., to all those involved in the project;
- enable the results of work and discrepancies to be clearly communicated back to the HF specialists.

Project plans and results of analyses pertaining to working-environment and safety shall be communicated to and dealt with by the relevant Working Environment Committee.

9. Was adequate consideration given to the division of human factors responsibilities between the different parties involved?

The division of human factors responsibilities between parties, e.g., client, operating company, vendor, engineering contractor, etc., depends on the type and scope of the project. Responsibility should be assigned for human factors input into:

- specification of general requirements and functional requirements (normally before signing a contract);
- functional specifications;
- control of detailed design of control centre and control room layout, displays and CRS applications software;
- technical specifications for the hardware and systems software; and
- delivery of systems and tools for implementation.

10. Were human factors requirements included in all subcontracts, and was a plan for periodical verification of subcontractors' compliance with these requirements developed?

It is important that contracts clearly state which requirements and specifications apply and how deviations from these are to be followed up. This is especially important where off-the-shelf solutions designed to the vendor's standard specifications are being bought, as these are more likely to have human factors discrepancies.

11. Were the content of HF deliverables and the expected timing of delivery clearly communicated?

Clear information should be given on deadlines and the content and form that deliverables should take.

12. Were steps taken to ensure that vendors' systems and products complied with company and regulatory requirements for human factors?

It is the responsibility of the operating company to ensure that the systems that vendors use to manage the work and the delivered products comply with human factors requirements, i.e., company standards and guidelines, and external requirements, e.g., government regulations and recognised standards.

13. Was an adequate human factors programme plan developed?

The plan should include:

- clearly defined HF programme goals;
- an outline of the HF elements/activities involved in the programme, i.e., the content;
- allocation of resources to each element in the plan. This is important since the scope of relevant human factors activities generally is underestimated;
- resource management, including internal project personnel resources and required external resources; and
- strategies and criteria for decision making and implementing recommendations.

For modifications and upgrades the plan should be consistent with the scope of the upgrade and should consider the effects of the upgrade process. This is to minimise any additional demands that intermediate designs make on the CCR operators. For example, the plan should include:

- planning the changes to minimise disruptions on operations
- co-ordinating changes with, e.g., training and procedure systems to ensure they are kept current
- conducting training on the new design before it is implemented.

☝ Changes made during upgrades can result in temporary designs that put different demands on the CCR operators than the starting or finished design.

Note: the Management Systems Regulation § 8 litera 2f sets requirements for documentation and information systems.

14. Were suitable processes and procedures developed for the human factors work carried out?

Work procedures for carrying out activities outlined in the HF programme should be developed, issued and maintained. These should document:

- *general process procedures,* i.e., an outline of the general process that the specialists will use to carry out the work;
- *process management tools*, i.e., tools and techniques to be used; and
- *integration of HF activities,* i.e., input from the HF activities to other design activities and vice versa

The procedures shall be available for inspection and included as reference documentation.

Note: the Management Systems Regulation § 8 litera 2g sets requirements for development of procedures and routines.

Note: NORSOK S-002 §s 4.1 and 4.2 contains a list of evaluations to be carried out as a part of the design process and specifies the content of the procedures to be developed in relation to these evaluations.

15. Were human factors activities within the design process given an appropriate schedule?

Appropriate scheduling should be used to ensure that the activities achieve the intended aim. For example, interfaces cannot be designed until detailed task analysis has been carried out to identify the necessary information requirements.

Note: ISO/FDIS 11064-1 gives guidance on the appropriate scheduling of human factors activities.

16. Was appropriate documentation produced and kept current, in order to provide a traceable record of human factors activities throughout the design process?

The results from the analyses and evaluations should be recorded, including any deviations from criteria or the planned methodology.

Note: the Management Systems Regulation § 8 litera 2f sets requirements for documentation and information systems.

17. Was the system for recording and tracking all human factors deviations and non-conformities satisfactory?

The system for tracking deviations should be able to handle human factors issues. All deviations and non-conformances should be evaluated for their potential effects. A decision then needs to be made and documented whether:

- to bring a deviation into compliance by modifying the design, selection of design alternatives, refinement of requirements, refinement of design criteria,
- to reduce potential effects through such means as procedure modifications or training, or
- to allow a deviation to stand without change if it is found to have negligible impact on the system.

This tracking should be done by existing systems wherever possible and should

- be known to those involved in the project;
- include a method to document and track issues from identification until they are resolved;
- assign responsibilities for evaluation, resolution and resolution acceptance.

Note: the Management Systems Regulation § 8 litera 2h sets requirements for handling of deviations.

Table 0. Checklist for Human Factors Programme Management

Review Topic	**Comments on quality of evidence**
1 Did the CCR design team include appropriate Human Factors (HF) expertise and competence for the type of project?	
2 Were the HF specialists given an appropriate position in the organisation?	
3 Were suitable workspace resources made available?	
4 Was training given in the use of the management system?	
5 Was a system developed to keep the CCR design team updated on changes in all relevant rules, regulations and standards?	
6 Was an HF leader identified for the HF specialists and his/her responsibilities, authorities, division of duties, communication and reporting lines clearly outlined?	
7 Were the roles of all other HF specialists clearly outlined?	
8 Were appropriate lines of reporting and communication developed?	
9 Was adequate consideration given to the division of human factors responsibilities between the different parties involved?	
10 Were human factors requirements included in all subcontracts, and was a plan for periodical verification of subcontractors' compliance with these requirements developed?	
11 Were the content of HF deliverables and the expected timing of delivery clearly communicated?	
12 Were steps taken to ensure that vendors' systems and products complied with company and regulatory requirements for human factors?	
13 Was an adequate human factors programme plan	

developed?	

14 Were suitable processes and procedures developed for the human factors work carried out?	
15 Were human factors activities within the design process given an appropriate schedule?	
16 Was appropriate documentation produced and kept current, in order to provide a traceable record of human factors activities throughout the design process?	
17 Was the system for recording and tracking all human factors deviations and non-conformities satisfactory?	

Step 1: Clarification of Goals and Requirements

Purpose

The purpose of this step is to ensure that general goals for the project are human-centred and that human factors goals and requirements are set.

Introduction

The role of the control centre and its relationship with the different subsystems e.g., process systems, power generation, maritime systems, drilling and well-interventions systems, communications systems, etc., must be identified and documented as part of the general project management, and project goals and requirements are then set in relation to these roles and relations. It is not within the remit of this methodology to address the technical and operational issues as such. It is, however, a part of the human factors programme to ensure these project goals take a human-centred approach and that specific human factors goals are set in addition to technical and operational goals. Currently project goals often fail to consider their effects on the CCR operator's role. Also, goals for the CCR operator himself are often overlooked. The CCR operator has to be considered in relation to technical goals and requirements to ensure that they are compatible with the goals and requirements relating to the working environment for the operator.

In addition to collecting together regulatory requirements, an important input to developing human factors goals is conducting an operational experience review (OER). An OER within the human factors activities of a project is directed toward existing designs that are similar to a proposed new design. It identifies both problems with these designs and good features that should be kept. This information is used to improve existing designs and to provide better starting information for the design of new or upgraded systems.

Objectives

- Ensure that a human factors Operational Experience Review (OER) is carried out and that the results are included in the goals and objectives for the new design
- Ensure that the general goals and requirements for operations, systems, equipment, etc., include HF issues
- Ensure goals specific to the CCR operator and his working environment are set in addition to those for operations, systems, equipment, etc.
- Ensure that incompatibilities between these goals are resolved satisfactorily

Regulatory Requirements

A list of regulations and standards that generally apply and set requirements for control centre design are found in the reference section for this methodology. The following government regulations set more specific requirements for this step:

- Management Systems Regulations: § 8 litera 2a
- Safety Regulations §§ 9 - 12 and 29
- SAM Regulations § 13
- Safety and Communications Systems Regulations §§ 13, 14 and 16

Other Standards and Guidance

- ISO/DIS 11064-1 International Standards Organisation (1999a)
- NUREG 0711 US Nuclear Regulatory Commission 1994

Information that can be Used for Review

- Methods and results of the OER
- List of project goals
- Lists of regulatory guides, standards and other formal documents
- Technical information on existing systems and control centres
- Project descriptions
- List of requirements for the control centre
- Operational Philosophy, Safety Philosophy documents
- Risk assessment documents
- Process descriptions, etc.

Review Guidance

1. Has a systematic Operating Experience Review (OER) been performed?

As a part of developing goals and specific requirements, an OER should be conducted. This includes:

- conducting interviews with personnel associated with management, operation, engineering, maintenance, etc;
- review of relevant mappings, improvement evaluations, etc;
- audits of other relevant control centres, i.e., analysis of similar installations;
- technology reviews, i.e., analysis of the latest operator system interface methods and technology.

2. Did the OER review previous installations or systems related to the proposed project?

The review should include information about human factors issues of:

- previous generations of the same systems; and
- highly related systems, plant or installations.

The guidance produced by the International Instrument Users' Associations (1998) points out that the amount and type of work depends on whether the project is a control centre modification (or extension) or a new plant design:

- *Modifications* — a situation analysis should be done in the existing control centre. An overview of functions in the new situation can be deduced by looking at what will be changed by the proposed project. There will be existing design constraints, but there should be better reference material available and better possibilities for making use of experienced operational staff.
- *New designs* — it may be difficult to find an existing and comparable situation for analysis, but full analysis of a completely new situation may be too time-consuming.

3. Did the OER include recognised industry issues?

For instance, the industry as a whole may be dealing with issues arising from:

- unresolved or generic safety issues;
- specific accidents;
- actions, letters, etc., from an inspection body such as the NPD;
- any central body that analyses accidents or collects injury and incident data;
- operating reports from particular types of equipment.

4. Did the OER review experiences with related technology?

The OER should address related technologies that have been used with the function being considered for change. For instance, if the design team is considering introducing alarm filtering, then experience with technologies for doing this should be reviewed. If experience with related technology cannot be found in the oil industry, then experience from other industries could be relevant.

5. Have the goals developed for the control centre been stated in a human-centred way?

Examples of such goals are that the control room will provide the CCR operators with:

- a safe and efficient means of operating the installation in all operational states and accident conditions.
- the interface and related information and equipment that are necessary to achieve plant operational goals.
- an environment where CCR operators are able to perform their tasks without discomfort, excessive stress or physical hazard.
- accurate, complete and timely information on the state of the installation's equipment and systems.
- necessary information to other facilities outside the control room.
- the means to operate the installation safely and to return it to a safe state after the onset of accident conditions.
- appropriate measures and barriers to safeguard the CCR operators against hazards such as unauthorised access, consequences of fire or explosion or toxic fumes which could endanger necessary operator actions.

- adequate routes for operators to enter or leave, or gain access to other control points in emergency conditions.

Note: the SAM Regulations § 13 requires objectives for the working environment to be drawn up.

Note: the Management Systems Regulations: § 8 litera 2a sets requirements for development of goals for the project.

Note: the Safety Regulations §§ 9 - 12 and 29 sets safety requirements for the project.

6. Were verifiable goals set where possible?

This makes it possible to verify that the final design meets the goals. In some areas measurable goals can be set, for example, goals relating to a reduction in lost time accidents or sick leave related to stress. In many cases, however, more detailed and verifiable goals cannot be specified until later on in the design phase. In these cases, after analyses have been performed the general, qualitative goals should be converted to measurable ones.

For example, regarding staffing of the control room, only a general safety goal such as, "The control room will be manned by the minimum number of CCR operators required to operate the installation safely." can be set at this stage. However, after the analysis phase of the project it should be possible to put a number on this. It is then possible to verify the staffing level is correct by using a table-top CRIOP at the end of the conceptual design phase and a full CRIOP at the integrated system testing stage.

7. Were conflicts between goals identified and resolved?

Once the goals are developed these should be reviewed to ensure that there are no conflicts between them.

8. Were all regulations and relevant standards to be followed identified, documented and available in the project?

A list shall be available and shall include:

- government and company regulations of management issues relevant to the project;
- all government regulations that set requirements for the control centre;
- all relevant standards that are recognised according to government regulations;
- all company specific requirements pertaining to the control centre; and
- other relevant standards (NORSOK, ISO, IEC, company etc) or guidelines that set requirements for issues concerning design of control centres, and that have been implemented by the project as specific requirements for the design.

Note: the Safety Regulations §§ 9 - 12 and 29 set safety requirements for the project.

Note: the Safety and Communications Systems Regulations §§ 13, 14 and 16 set requirements for safety systems and communication systems.

9. Were the applicable requirements considered and documented?

A list should be made of all *applicable* requirements as set in the relevant regulatory requirements and standards listed in the previous question.

In the future, modification projects will become more frequent. Depending on the nature and extent of the modification, different sets of requirements may be applicable to new and existing parts of the control centre. The NORSOK standards are applicable to all significant new modules and solutions. However, a close evaluation of how the changes affect existing parts needs to be carried out, in order to identify which requirements should apply to the control room as a unit.

Note: ISO/FDIS 11064 part 1 Annex B contains a list of requirements for consideration.

10. Were constraints to the project identified and documented?

There will be constraints that affect the project, whether it is a new control room or a modification, e.g., time, funding, available technology, staffing, space availability, and the limited extent to which current jobs and organisation can be changed. These should be identified at this stage of the project and used as input at the other stages.

For example, if an existing control system must be used this will have an effect on the design of screen displays and the navigation within the system. For this reason, constraints from equipment being supplied by vendors should also be considered at this stage.

Note: ISO/FDIS 11064 part 1 Annex B contains a list of constraints for consideration.

11. Were conflicting requirements and constraints identified and resolved?

Conflicting requirements and constraints should be identified and an appropriate solution reached as early as possible in the design process. Operating requirements, safety requirements and human factors requirements defined in regulations and standards referred to in this document, and requirements set from operating company policy or as a result of the OER should be examined to ensure that no conflicts arise. Where they do arise, they must be resolved according to a set of criteria that include:

- safety has a higher priority than production; and
- measures reducing the probability of accident shall be given priority over mitigating measures.

12. Have Operational, Safety and Alarm Philosophy documents been established?

These should describe the main operational and administrative activities to be carried out in the control centre and outline its role in all operational states. These documents should be written with a human-centred approach and the human factors issues described in this methodology should be considered when establishing these documents.

Table 1. Checklist for Clarification of Goals and Requirements

Review Topic	**Comments on quality of evidence**
1 Has a systematic Operating Experience Review (OER) been performed?	
2 Did the OER review previous installations or systems related to the proposed project?	
3 Did the OER include recognised industry issues?	
4 Did the OER review experiences with related technology?	
5 Have the goals developed for the control centre been stated in a human-centred way?	
6 Were verifiable goals set where possible?	
7 Were conflicts between goals identified and resolved?	
8 Were all regulations and relevant standards to be followed identified, documented and available in the project?	
9 Were the applicable requirements considered and documented?	
10 Were constraints to the project identified and documented?	
11 Were conflicting requirements and constraints identified and resolved?	
12 Have Operational, Safety and Alarm Philosophy documents been established?	

Step 2: Function Description and Analysis

Purpose

The purpose of a function description and analysis is to determine the needs for human factors involvement to achieve objectives defined in Phase A of a project (ISO/FDIS 11064–1, p.11). During systems design for a new control centre (or upgrading of an existing facility) the design team states the purposes or objectives of a system, as well as systems requirements and constraints. These objectives translate initially into high-level functions that gradually become better defined.

Introduction

A control centre is defined in ISO/FDIS 11064–1 as a combination of control rooms, control suites and local control stations that are *functionally* related and all on the same site. The Safety and Communications Systems Regulations define a control centre as a continuously manned room for safety surveillance and control of the installation, which is a narrower definition. It follows in either case that one first needs to understand the functional purpose and functional relationships of a proposed control centre (or modification to an existing centre) in order to design it adequately.

There is no automatic guarantee that new or upgraded control centres allow humans and machines to do tasks as effectively as their predecessors do. Because the way that tasks are done is altered, there is the possibility that either operator-tasks or machine-tasks (or both) do not deliver/support the required functions correctly. This in turn means that the control centre may not support the installation in the expected way. This could be due to a failure to appreciate how new systems change the way that people and machines work together. The most common failure is to do the functional design (i.e., this step, Step 3, and Phase B's conceptual design work in general) too late or not completely enough.

Previous operating experience (or Step 11 in other projects) or regulatory requirements may require that the new design is adequate to deal with certain scenarios. It is important that the right events, scenarios, etc., are chosen. If it is intended at a later Step to change a function allocation (for instance, by reallocating tasks or by automating tasks), it may be necessary to assess whether performance will be satisfactory under the new arrangement.

A complete functional description of a control centre can also act as a resource for possible future changes, such as changes in location, equipment, support systems, manning, and organisation. The description of functions and allocations lets users and project teams understand more clearly the effects of introducing changes, allowing for better design requirements on the control centre. The transition period can also be planned better, for instance, by designing new training, writing documentation, etc.

Acceptance of a function analysis (together with the function allocation that follows in Step 3) should be based on conformance with review criteria, including:

- identification of safety functions and processes;
- identification of processes and functions that have been changed from the previous installation or system;
- documentation of the technical basis for changed processes;
- a summary description of plant processes; and
- a detailed narrative description of changed processes.

Objectives

A function analysis aims to describe all anticipated functions of the controlled system, namely:

- *operational functions* — for reaching production goals using the available process equipment and automation, including process control, assessment of process state, off-normal handling, operations administration;
- *improvement functions* — for example, tuning of process equipment and automation, testing and implementation of software control applications;
- *maintenance functions* — for preventative and corrective maintenance of equipment, first line maintenance of automation, maintenance of process equipment;
- *training functions* — for example, training of new operators, learning how to cope with certain off-normal situations, learning to work with new tools and applications;
- *emergency/abnormal operation*; and
- *management of local organisation* — organisation of operator teams, some personnel management, co-ordination with supervisors and installation management.

Regulatory Requirements

- SAM Regulations
- Safety Regulations § 14
- Safety And Communication Systems Regulations §§ 14, 15, and 16 litera e
- Emergency Preparedness Regulations § 17
- Explosion And Fire Protection Regulations § 33
- NORSOK O–DP–001 § 7.2
- NORSOK C–001 § 6.5
- NORSOK I–CR–004
- NORSOK S–002 § 4.9.5

Other Standards and Guidance

- Problem-solving the FAST way. Creasy (1980)
- ISO/FDIS 11064-1 International Standards Organisation (1999a)
- A Guide to Task Analysis. Kirwan and Ainsworth (1992)

- NORSOK I–002 § 6.4.1

Information Sources for the Reviewer

Information that can be used both in the design work and in reviews of the design include:

- functional objectives from phase A;
- drawings of analysed function hierarchies;
- tabular information on functions;
- descriptions of functions; and
- an operating experience review.

Review Guidance

1. Was a there a documented choice of method for the functional analysis?

It is best to use a method that keeps the functions relatively abstract, i.e., not too detailed or finely decomposed. They should not be described, at this stage, in terms of human or machine performance, to avoid pre-empting later decisions. In later stages, tasks are allocated to humans and machines, and the definitions of functions and sub-functions refer to humans and machines more explicitly.

2. Was a function analysis completed using the method?

Function analysis should represent the most general objectives of the installation and operating staff. The analysis should be performed using a described method. Recognised methods (see the appendices to this step) include:

- *Functional flow diagrams* — these are block diagrams that illustrate the relationships between different functions. They are constructed by identifying the functions to be performed in the system. These are arranged and connected with directed lines ( ) and gates (*AND*, *OR*) representing the inter-relationships between functions. The technique is useful for helping to determine how to allocate and order functions in a complex system, and to ensure that all the necessary functions are provided in Step 3. However, the information in the diagrams is only of limited use in the detailed analysis of tasks performed in Step 4. See Kirwan and Ainsworth (1992).
- *Hierarchical Task Analysis* (HTA) — this produces a hierarchy of goals, operations and plans. If used at a high level this can be useful in function analysis as well as systematically throughout a project but especially in Step 4, to help designers describe how tasks should be carried out. See Kirwan and Ainsworth (1992).
- *Function Analysis System Technique* — 'FAST' is a sub-technique of HTA It is useful in the early stages of design. It is similar to HTA in appearance but is directed solely at system functions. A statement containing an item, verb and a noun defines each function. These are arranged hierarchically as for HTA. See Creasy (1980).

The function analysis should include the systems associated with each selected operating event.

3. Were all operational functions and safety functions identified?

This may include any applicable mandatory regulatory assignment, performance aspects (e.g. response time accuracy), safety principles, availability and reliability requirements,

maintenance principles, utility practices for shift manning, feedback of experience from previous designs and so on.

Safety functions include those required to mitigate or prevent accidents that could cause undue risk to health, safety and environment. For each safety function, the set of plant processes (system configurations or success paths) that are responsible for the function or capable of carrying out the function should be defined. In cases where there is an incremental upgrade, there should be a check of any safety functions allocated to the new systems versus the old systems.

Note: the comments to Emergency Preparedness Regulations § 17 note that ergonomic design of the control centre is one of the measures that can prevent hazardous situations from developing. Furthermore, emergency preparedness may need to be reassessed if, amongst other things, there is an alteration of the operational scope of an installation (p. 27).

Note: the Safety And Communications Systems Regulations lay down certain requirements for display of information from emergency shutdown systems, process safety systems, etc., in the control centre.

Note: the Explosion And Fire Protection Regulations § 33 set out requirements for fire pumps in relation to the control centre.

Note: the Emergency Preparedness Regulations states that personnel in the control centre may have specific duties for communication during emergencies.

4. Was the identification of functions complete?

For example, it is common that operational staff have additional administrative tasks, paperwork, etc., that may not be thought of as directly operational functions or safety functions. It is important that this workload is recognised, and designed for. Relevant functions include:

- safety functions;
- process operation functions;
- administrative functions (work permit, reporting, communication, training, etc.); and
- secondary functions (meeting area, rest area, etc.)

NORSOK I–002 refers to information presentation on display screens consistent with function, which implies that their functions (and the tasks they are used for) need to be defined clearly.

NORSOK I–CR–004 refers to limitations on personnel traffic in the control room. This implies limitations to the functions that can be allocated to the CCR.

5. Was sufficient information gathered on functions?

The design team should use a top-down approach. This helps to ensure that all operational functions and tasks are considered. The approach starts with a review of all plant functional goals, supporting systems, sub-systems and their functions. Information gathered at this stage is useful in conceptual design and detailed design.

6. Was there a check that the function analysis was complete and correct?

It may be useful for the design team to carry out a peer review (probably best done after function allocation). The objective is to check the completeness and correctness of the function analysis and function allocations.

The review should confirm that:

- all the functions necessary for achievement of plant operational and safety goals are identified;
- the proposed function allocation (discussed in Phase B, Step 3) is in accordance with criteria established for allocation, including completeness;
- all the constraints on each function are identified, including performance aspects, those derived from safety principles, availability principles and station operating principles, and those derived from other standards and regulations;
- requirements resulting from higher and lower functional goals merge under all operational modes without conflict.

Note: NORSOK I-CR-004 set requirements for marine control systems in the CCR.

7. Were the events or scenarios chosen for function analysis representative for all anticipated modes?

Past operational records (or the resolutions from Step 11 of other projects) may reveal new operating situations, or variations on them, for which new or changed allocations need to be made. For instance, evolutionary changes in the installation may have created or changed tasks, procedures and emergency scenarios.

In addition to normal, incident and emergency conditions, events caused by a representative combination of multiple failures leading to maximum operator workload must be considered for the assessment of functions.

The selected events should be relevant to the overall scope of the project. The events should include the Man-Machine Interface components being modified or designed.

Note: NORSOK O-DP-001 § 7.2.1 lists normal operating modes that are the basis for system design and equipment selection and also refers to commissioning and start-up requirements.

8. Did the work include all relevant locations?

Affected areas that sometimes need to co-operate closely with the control centre could be:

- auxiliary shutdown rooms and panels (e.g., manual ESD release stations);
- local control panels or stations;
- other controls, switches, valves and breakers that are operated or consulted during normal, abnormal or emergency operations,
- remotely operated facilities.

The focus of work is often the main control centre. However, the design or design change may affect several other areas. It is important that these are included in the design process. New or changed function allocations may be needed in several areas, such as new local control panels, rearranged control centre facilities, and auxiliary shutdown facilities (if these are part of the design). Many things can affect function allocation such as advances in instrumentation, displays, operator support systems, and changes in operating philosophy with remote operations. Reviews typically find that control points outside the main control centre are often the source of human factors weaknesses.

9. Were sequences of functions considered?

Sequences composed of functions assigned to the control-room staff and to automation should be mutually consistent and complete. Analysis is likely to find many functions that are currently shared between human and machine, or between several operations staff. Any changes to functional design and allocation should check that sequences of use, and co-operation between humans and machines, remain satisfactory.

10. Was there a preliminary consideration of functional areas for the control centre?

The control centre should ideally be divided *preliminarily* into functional or operating areas. These should cover the various operating conditions, including start up, normal operations, shutdown and emergencies.

The functional description of a control centre allows decisions to be made and documented about the functional layout of the control centre. This is useful so that the detailed design team later knows the design basis of the control centre space. This is useful information for the conceptual design phase, in particular Step 7, and for detailed design stages. It is also useful for designers of future upgrades to the control centre.

NORSOK I–002 § 6.4.1 refers to the number of operator stations in the CCR.

NORSOK C–001 § 6.5 refers to the placement of the CCR relative to other facilities.

Table 2.1. Checklist for Function Description and Analysis

Review Topic	**Comments on quality of evidence**
1 Was a there a documented choice of method for the functional analysis?	
2 Was a function analysis completed using the method?	
3 Were all operational functions and safety functions identified?	
4 Was the identification of functions complete?	
5 Was sufficient information gathered on functions?	
6 Was there a check that the function analysis was complete and correct?	
7 Were the events or scenarios chosen for function analysis representative for all anticipated modes?	
8 Did the work include all relevant locations?	
9 Were sequences of functions considered?	
10 Was there a preliminary consideration of functional areas for the control centre?	

Appendix 2A: An Example Technique for Functional Description

Introduction

Two essential parts of functional design are:

- *Analysis of functions* — the tasks to be performed by the designed system first need to be identified (the subject of Step 2)
- *Analysis of Assignments* — how the tasks are allocated to machine, human or both (the subject of Step 3)

The 'designed system' means the control centre or control suite, at the top level. Within it are various locations, systems, items of equipment, procedures, people, etc., which together support the performance of functions.

The example method given here for the function analysis stage consists of two stages:

- Drawing of a function hierarchy
- Tabular description of each function in the hierarchy.

Function Hierarchy

One technique for describing functions is called 'FAST' (Function Analysis System Technique). This technique organises functions and sub-functions into a hierarchy. It visually displays the relationships between all functions that must be performed to achieve a basic function.

The diagram below shows how to think about functions and how to identify them within a hierarchy. High-level purposes and constraints can be taken from Phase A of the design (goals and requirements).

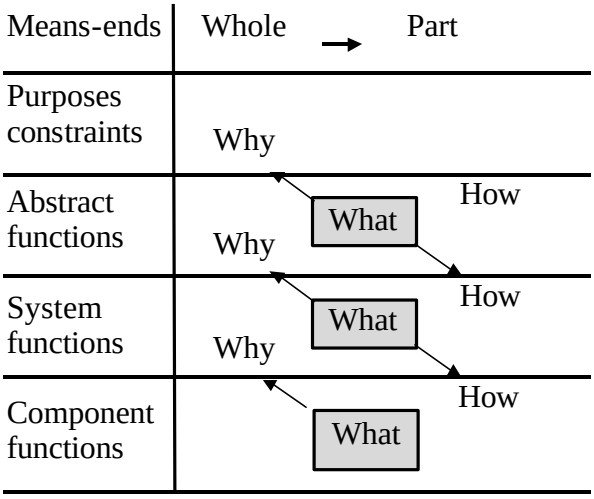

Figure 2.1. 'Why', 'what' and 'how' of functions

Table 2.2. Method for Identifying Functions describes a procedure for identifying functions in a hierarchy. As many levels as wished could be used, depending on the degree of detail needed in the analysis, but deep and multiply-branching hierarchies quickly become unmanageable.

The resulting hierarchy has abstract, high-level functions at the top, system-level functions in the middle, and detailed, equipment-level, or component-level functions at the bottom levels.

Table 2.2. Method for Identifying Functions

1. **Find out what the control centre, and the systems and people in it, need to do.**

   What are the qualities and characteristics of each thing they need to do? Why is each function needed?

2. **Ask questions covering 'why', 'what' and 'how' for each function**

   'Why' will reveal higher functions or the purpose of a function. 'What' will reveal the characteristics of the function - what it does. 'How' will reveal lower functions

3. **Try to use only one verb and one noun to describe a function.**

   The verb answers the question 'What does it do?' The noun answers 'What does (person or machine) do it to or with?'

   Where possible, verbs should be action-oriented.

   - Avoid passive, vague or indirect verbs like 'is provided by', 'supplies', and 'gives'.
   - Avoid goal-like words, such as 'improve', 'maximise', 'minimise', 'optimise', 'prevent'

4. **Select the best verb-noun pair from several choices or use a team to come up with a group definition.**

   At first, the study team might come up with several phrases that describe nearly the same function. Select the best one

   It helps for future reference to give each named function a hierarchical number

Once the functions have been identified, they can be arranged in a diagrammatic form. This activity can proceed in parallel with the first step of the functional analysis, because it is easier to see where functions are missing when the work so far is available in diagrammatic form. Table 2.3 outlines one method for constructing the hierarchical diagram.

Table 2.3. Method for developing a FAST diagram

1. **Define all the functions performed by the control room and its elements with the two-word function descriptions.**

   Use the labels agreed in the initials, or come back to this step iteratively.

   Write each function on a separate small card. Lay out the cards on a large surface. It is not a good idea to use a computer drawing tool at this stage because the screen is too small and it is not so easy to reposition and arrange functions.

2. **Select the cards that best describe the most abstract functions**

   These include the ones taken from the initial analysis work in Phase A, but more will have been identified.

3. **Create a branching tree structure, putting an abstract function at the top.**

   Start with one function. Ask 'How does (the control centre or element in it) do this?' E.g., How does the operator start the fire-sprinklers? Place answers to the question on another card to the right. Repeat until branching has stopped. Repeat for other abstract functions, until you have at least the abstract functions and system functions in a logical sequence.

4. **Verify the structure in the reverse direction …**

   … by asking the question 'Why does (the control centre or element in it) (verb) (noun) e.g., Why does the operator start the fire-sprinklers? The how-why questions are used to verify the logic of the entire diagram. The sequence of functions on a branch must make sense: reading to the right for 'how' questions and to the left for 'why' questions.

5. **Write down the FAST diagram in graphical form …**

   …and number the hierarchy to aid cross-reference to the tabular description which follows.

Once the functions have been identified and labelled, each function should be transferred to a tabular format so that information on each of them can be collected.

Tabular Function Analysis

Each of the headings in the function hierarchy can then be described in a tabular form according to the particular needs of the project. An example template is shown in Table 2.4.

Table 2.4. Template for Tabular Description of Functions

Function No.	Function Name	Who	Start conditions	Information	Manoeuvre	Method	Comments
1	2	3	4	5	6	7	8

Key:

1. This gives the number of the function taken from the hierarchical analysis. It is an arbitrary label given for ease of reference.
2. This gives the name or short description of the function chosen for the hierarchical analysis.
3. This says who in the control centre has the main responsibility for the function. If other people help with the function, these are explained in 6 or in comments in 9.
4. This states the starting conditions or 'trigger' for the function. Some functions may be continuous, others can be triggered by an event like an alarm.
5. This states the information needed for the function. This should also say where the information source is located.
6. This describes the control action, including the general control room location, the equipment that is used, and who does it.
7. This states how the function is carried out – its 'method'.
8. This is space for any additional comments.

Appendix 2B: Principles for the Process of Functional Design

To carry out successful functional design for a new facility (or upgrade) there needs to be a suitable team and *process* for doing the work. This section gives some guidelines for setting these up. Many of these guidelines will be useful for all kinds of human factors work in a control centre design or an upgrade, not just functional design. Since functional design comes early in the design process, the preparatory work is more important and can contribute to a smoother process for other design work, including detailed design stages.

Improvements in the control centre should be based on operators' real needs. The control centre's operational philosophy and operators' roles should not be changed needlessly. New systems should be the same as old systems where those are satisfactory. The new systems and functions should also be consistent with any systems retained from the previous design.

The plan in the following sections describes verification and validation[1] of functional design. The correct assignment of functions to man and machines should be verified and validated. Verification of function allocation means the presentation of evidence that the allocation of function is in fact in line with the criteria and specifications for function allocation developed for the project.

We suggest that a verification and validation process should include preparation, evaluation and resolution phases. The sections and guidelines below are based on these processes. The guidance is *not* given in the form of a checklist, because this appendix is a guide for good practice, rather supporting specific regulatory requirements.

Preparation

1. The team should identify relevant source documents

All the documents generated and used by the project in general could potentially be of use during functional design. For modifications rather than new designs, a subset could be used.

Analysis should be based on accurate information sources. Descriptions of plant systems, schematics, P&I diagrams, safety analysis reports, etc., Plant procedures, emergency response guidelines, technical specifications and personnel training materials will also specify functions and tasks.

There are several sources of documents relevant to functional design:

- *Safety and licensing documentation* — systematic reviews and analysis, safety goals and principles, operator response guidelines and event sequence diagrams
- *Control centre design documentation* — previous control centre experience, human factors principles, design guides
- *Plant design documentation* — production goals, performance specifications, initial plant description, process and instrumentation diagrams

[1] ISO/FDIS 11064-1, p. 3, defines *verification* as the process of examining the result of a given activity to determine the conformity to the stated requirements from that activity. The same standard defines *validation* as the process of examining a product to determine conformity with user needs.

- *Operations and commissioning documentation* — previous operating manuals, initial operating policies and principles.

A document structure should be developed, along with a review and approval procedure, with the outcome being the availability of documents to all design personnel. This helps to ensure uniformity of design by establishment of continuity and convention.

The documentation should include material produced specially for an upgrade, and more general information, such as standards, guidelines and human factors literature. The documents could include:

- Normative documents
- Human factors literature and guidance specific to functional design
- Licensee event reports
- Failure analyses
- Safety analyses
- Incident and accident analysis reports
- Feedback from experience with previous designs
- Contract requirements
- Systems descriptions
- System specifications
- Task analysis documents
- Control room assessment
- Generic control room design report
- Panel or workstation drawings
- Lists of acronyms and abbreviation
- Descriptions of coding conventions
- Man-machine interface style guides
- Computer-processing specifications (e.g., alarm-processing)
- Procedures
- Operator training manuals

The team should have access to applicable documents prior to the beginning of the work. Accidents, reports, operating experience, previous alterations to equipment may give indications on where changes to functional design need to be made. The team may need to be given special access to these, or to be helped with searches.

2. The team should have access to a review of human factors operating experience.

Operating experience (produced by Step 11 of related projects) may be a source of information or indications that past functional designs have not been entirely satisfactory. There may be instances where automation has not worked particularly effectively. There may also be manual tasks on older systems that can now be reallocated partially or totally to machines.

The resolution of issues that are found in a review of operating experience can influence almost any human factors issue, such as training, staffing, procedures and equipment design, not just functional design. An operating experience review can influence a functional analysis for an upgrade project by indicating:

- Tasks and functions to be evaluated
- Events and scenarios to be selected
- Issues that need to be resolved in the new or evolutionary design

3. The team should have an appropriate position in the organisation.

The team should have responsibility, authority and placement within the organisation to ensure that commitment to the work is achieved. Function analysis can be time-consuming unless there is previous work and documentation available. If the team does not have sufficient authority, there may be successful resistance to change or to the use of time and resources on the work if it appears inconvenient.

4. There should be a suitably composed team for the functional design.

A team should include design, operations and safety staff. (It should be understood that this team will carry out all work on an upgrade, not just the functional design.) The composition of the team will vary according to the size of the task or modification. A basic technical team that has functional design as one of its tasks will usually include these areas of expertise:

- Systems engineering, instrumentation and control systems design
- Architectural design and civil engineering including control centre and control panels
- Systems analysis including digital information and communications systems design
- Human factors engineering
- Plant operations, management and training
- Plant hands-on operations and maintenance experience
- Safety requirements

The specific areas of expertise with representation should be based on the scope of the work and the upgrade. Operating experience is particularly important. The number of members of the team should be kept small commensurate with efficient work and communication, so as to concentrate the workload on a few team members, who then become expert and more efficient. Expertise can be called in as necessary for topics or areas of expertise not covered by the team.

5. The team should be independent of other design teams.

The members of the team should have some independence from the designers of the systems they are evaluating or describing.

6. The team should have suitable resources.

This refers to the resources, workspace and equipment required by the team to do the selected functional design work. There should be appropriate space for the team and any part-time consultants and specialists. There may be special equipment requirements.

7. The team should have suitable working materials.

The team should develop standard procedures, data sheets, etc., for conducting the functional design to systematise the effort

Evaluation

8. The review of the functional design should be documented and traceable.

The method used must be fully documented. The objective of the reviewers is to establish that this method was in fact followed. Functional analyses need to be documented in hierarchical form and descriptively. Function allocations should be explicitly documented.

9. The results of the work should be recorded satisfactorily, including deviations, non-conformities and assessments against criteria.

The results from the evaluation should be recorded, including any deviations from criteria or the planned methodology.

Resolution

10. There should be satisfactory resolutions developed and recorded for all deviations and non-conformities.

There should be evidence that any deviations found in the evaluation (including failures to reach criteria and non-conformities) have been acted upon. The process for the consideration of these aspects should be systematic and documented. All deviations may be evaluated for their potential effects and then addressed by the review process. A decision then needs to be made and documented whether to:

- Bring a deviation into compliance by modifying the design, selection of design alternatives, refinement of requirements, refinement of design criteria,
- Reduce potential effects through such means as procedure modifications, training, or
- Allow a deviation to stand without change if it is found to have negligible impact on the system.

11. There should be checks for side effects of changes.

There should be evidence that the evaluation team has considered the possibility of side effects of any changes made because of deviations or non-conformities. For instance, a determination on human factors grounds that labelling in the control room needs to be changed may need to be reconciled with the prevailing plan for labelling and tag-numbering in the rest of the plant. It is important to ensure that on-going modifications do not conflict with other design issues and that they confirm the design basis

Appendix 2C: Principles for Hybrid Designs and Upgrades

It is now commonly accepted that human factors is an important subject contributing to safety and reliable human performance. Errors involving operators in the control centre can contribute to accidents and incidents. This section gives some guidelines for functional design that apply particularly to upgrade projects, as opposed to new control centres.

The ultimate responsibility for safe operation of an installation lies with the operating company that owns or operates the plant. The day-to-day responsibility lies with the operations staff. To discharge this responsibility, the staff making up the control centre must operate and interact with systems that they cannot observe or handle directly. To do so, they rely on information, displays, controls and procedures to provide them with the necessary means to make decisions and send instructions back to remote systems from the control room. It follows that the quality of the systems that the operators use can greatly affect performance. The capabilities and limitations of the human operator also affect functioning of the human-machine system, seen as a whole. The two (people and machines) must be understood so that the system as a whole performs to the desired level.

In function design and function allocation, functions are defined for the operators carrying out their tasks. Whether this design and allocation is implicit or explicit does not alter the point that a design decision is made in practice. The operator's role can be an active one, in which the operator serves a complementary role to machines, oversees the plant, and decides which systems to activate and when to issue instructions to systems. The equipment used in the control centre, and its design, shape operator performance and determine to a large extent how efficient the operators can be in performing their designed allocations and roles. Therefore, changes to the technology, systems and support equipment in the control centre must be examined from the human point of view, since it is through these systems that safety-related and performance-related actions will be carried out.

Besides major periodic refits or even relocation of the control centre, existing control centres are likely to undergo almost continual gradual change. The human factors work involved in a smaller evolutionary change will be considerably different from a new advanced control room.

Evolutionary changes can be necessitated for a variety of reasons, such as:

- regulatory requirements,
- ageing of existing systems,
- introduction of new technology, and
- operating experience.

For a new control centre, the full range of human factors issues, and standards that deal with them, are likely to be important. For smaller, more evolutionary changes, the most important human factors issues will depend on the nature of the modification.

The verification and validation of functional assignment is relevant both to the design of new systems and to upgrade projects, where in either case the role of the operator will change.

Extensive top-down function analysis may not be necessary if functionality can be shown from existing documentation and if there are successful arguments for qualification by similarity, by showing that the change is similar to an existing system that has already been qualified. Any changes in function assignment and their integration with other functions should be verified and validated.

Very little practical guidance is available on human factors in upgrade projects. Some sources suggest that existing human factors information can sometimes be re-used. Arguments that the proposed changes are acceptable can be based on the degree of innovation versus the degree of similarity to previous designs or generations. These arguments can justify the use of existing data and help to reduce the amount of new design justification needed, including human factors justification. New human factors work is focused on areas of change and their integration with the existing system.

The human factors work itself must still have an acceptable framework supported by appropriate documentation. Final determination the amount of human factors work that is acceptable for evolutionary upgrades may well be set by the regulating authority in co-operation with the operator doing the upgrade.

The guidance is *not* given in the form of a checklist, because this appendix is a speculative guide for good practice, rather than something that is related to regulatory requirements.

1. **Consider hybrid control room designs rather than complete control room replacements.**

   In order to introduce new technology into an existing installation, a hybrid step can be an acceptable alternative. For example, VDU display units could be introduced into an existing control centre with conventional panels. There may be some advantages to this approach, for example:

   - Adaptation, training and acceptance by the operators may be easier
   - Experience can be gained without affecting production
   - The licensing process can be taken step by step.

   A hybrid solution may actually provide the best combination of traditional and advanced systems from the point of view of what operators actually find helpful.

2. **Consider implementing functions the same way in the upgrade as in the old design.**

   Offering the same functionality may allow an easier transition to the new system from the old. The involvement of the operators may even lead to the decision to keep to the existing presentation scheme. However, it will also probably be desired to use new possibilities for operator support and integration of information. New technology makes it possible to integrate information from several sources, correlate information and present it to operators in overview displays, while still giving the possibility for detailed analysis if required.

3. **Use experience on the effectiveness of the existing systems.**

   Experience gathered during normal plant operation is valuable, but this does not normally exist in written documents, unless there have been periodic operating experience reviews (see Step 11). Operations people hold the knowledge. If there have been disturbances, trips, and

incidents involving human actions, reports should be available and should be analysed. The analysis should look for possible weaknesses in the existing design, which should be overcome in the new design. Existing systems may have good operational records. Key important design features should be identified and carried over to the new design.

4. Involve operations people early in the upgrading project.

Involvement of operations people early in the project makes it more likely that operational experience and requirements are carried over to the design team. What is more, it the is operations people who will have to live with the changes, so they need to be sure that their specific needs and requirements have been taken account of in the design.

5. Involve human factors expertise at all stages of an upgrade project, including requirements specification and functional design.

People with human factors responsibilities should be assigned to the upgrade project team. Several types of questions should be considered during an upgrade. For instance:

- How does the operator interact with the system?
- In what ways can the new system potentially be misinterpreted?
- What are the possibilities for errors with the new system?

Step 3: Function Allocation

Purpose

Function allocation is closely connected to function analysis (Step 2). The overall objective is to achieve an allocation of functions that takes into account the strengths and weaknesses of humans and machines. Function allocations help to shape the detailed design requirements for the control centre.

Introduction

When a design is created or upgraded, changes can be expected in:

- *allocation of function* — the way in which functions are assigned to humans or machines and, consequently,
- *joint human-machine system performance* — the way that humans and control centre equipment and systems interact and jointly perform the tasks required of them.

The overall performance of such systems is sensitive to the interaction between human and machine. One cannot design engineering systems in isolation and expect them to reach performance targets. One must consider the performance of people and machines as joint systems. A typical fault is to introduce an upgrade that, on the one hand, only partially replicates the functions of the old system and, on the other hand, takes over some functions from other systems. Such shifts of allocation and even duplications of system functions are more likely if there are not explicit function analyses and allocations.

Objectives

The specific objectives of function allocation are:

- to enable all safety, functional and performance specifications to be met;
- to cover all credible combinations of state of the installation, events and scenarios;
- to make best possible use of manning and automation; and
- to define the correct relationship between manning and automation.

Outputs of this step are defined in ISO/FDIS 11064–1, p.11.

Regulatory Requirements

- Explosion And Fire Protection Regulations §16
- NORSOK S-002, § 4.9.5
- SAM Regulations, §§ 16 and 35
- Explosion and Fire Protection Regulations § 16

Other Standards and Guidance

- Problem-solving the FAST way. Creasy (1989)
- IEC 964 International Electrotechnical Commission (1989)
- ISO/FDIS 11064–1 International Standards Organisation (1999a)

Information Sources for the Reviewer

- An operating experience review (see Step 11) and/or operating experience from similar projects
- Results of phase A, such as an overall operating philosophy and goals
- Results of functional description from Step 2.
- ISO/FDIS 11064–1, p.9, gives a list of requirements and constraints that need to be taken into account.

Review Guidance

1. Was a method for chosen and documented for the functional allocation?

ISO/FDIS 11064–1, p.11 describes a basic allocation procedure.

2. Did the function allocation follow operating principles?

Control room function design and function allocation should follow the operating company's principles. For example, there may be a centralised control philosophy; there may be restrictions on the availability of supporting staff for any necessary local actions.

Note: the Explosion and Fire Protection Regulations § 16 refers to the design and location of the main areas of an installation so as to minimise risk to people, the environment and assets.

3. Was the allocation of functions adequately done?

The results of the previous functional description should be used at this early stage of design. They can be used to find out which functions are affected by a proposed change. It should be documented how the changed system will support all affected functions.

There is no way to allocate functions purely by following a formula. Instead, one has to rely on expert judgements. Therefore, it is important to make visible the process and judgements that went into the allocation at this conceptual design stage. This allows the design team to know the full background to allocations if they need to consider a change of compromise at detailed design stage (see also question 6).

Typically, functions assigned to people are:

- manual control including backup control to automatic control;
- monitoring associated with both manual control and automatic control;
- high-level mental processing tasks such as diagnosis to determine the cause of abnormal and unforeseen operating conditions and events and to determine the corrective actions.

ISO/FDIS 11064–1, p.10 notes that the design team should also consider the variability of the users, e.g., age, experience, abilities.

Note: the guidelines to the Emergency Preparedness Regulations § 26 refer to the need to avoid incompatible duties in a situation of hazard or accident.

4. Were there criteria for allocation of functions?

Criteria for assignment of functions to operator, operator support systems or automated systems should be based on suitable and explicit characteristics.

- *Performance* — priority, accuracy, precision, complexity of decision-making within time limits.
- *Complexity* — number and sequence of control actions.
- *Importance* of decision-making for plant availability and safety.
- Necessity for *enhancement of operator's capabilities* in decision-making activities, e.g., diagnostic monitoring and high-level mental processing, information processing and storage.
- *Solution flexibility* — the need for alternative solutions and the degree to which pre-defined solutions are available.
- *Environmental considerations* — sensitivity/tolerance to external and environmental factors.
- *Cost* — implementation cost and operational cost.

Assignment criteria are described in IEC 964, A.3.2.2 and the assignment is described in A.3.2.3. Also, ISO/FDIS 11064–1, p.11 describes a basic allocation procedure.

5. Was there a clear result from the function allocation process?

The functions resulting from a function analysis can be grouped into:

- *Functions that must be automated* — e.g., functions requiring rapid performance, high repeatability, or where the consequences of error are severe. Sometimes, a certain allocation may be required by law or regulation.
- *Functions that are better automated* — e.g., lengthy tasks, functions requiring high accuracy or involving a degree of risk to the operator.
- *Functions that should be assigned to humans* — e.g., those that require human or inferential knowledge or flexibility, those that include tasks in extreme abnormal or accident situation where automation is difficult or impossible.
- *Functions that must be shared between humans and machines* — e.g., where automation is used to detect and annunciate plant conditions, and to process information for the operator to make judgements and control actions.
- *Functions that are allocated because of cost* — a function may be allocated to a human simply because there is no compelling reason why they should not perform the work, and the balance of costs favours the human.
- *Functions that are allocated because of the human's job design* — sometimes, decisions on other criteria are overridden because humans need to be kept 'in the loop' so that they are ready to make decisions and take actions. Such judgements are difficult to make, but they can be estimated from experience with similar systems and from self-report data. Similarly, some functions may be allocated to operators to maintain satisfaction and interest.

Very few functions can be allocated wholly to either humans or machines; most must be allocated to some combination acting together. Initial function allocations can be based mainly on past practice. This reduces the effort required at this step. In such a case, the function allocation step consists mainly of checking that the allocations are reasonable.

6. Was there a reconsideration of function allocation?

Function allocations can potentially be affected by job analysis and any reviews of conceptual design, for example, in Step 8. If this is the case, this step should be revisited. The *general* rules for function allocation should be viewed as a starting point only. *Detailed* decisions may later depend on the judgement of the design team and operations staff.

Table 3. Checklist for Function Allocation

Review Topic	**Comments on quality of evidence**
1 Was a there a documented choice of method for the functional analysis?	
2 Did the function allocation follow operating principles?	
3 Was the allocation of functions adequately done?	
4 Were there criteria for allocation of functions?	
5 Was there a clear result from the function allocation process?	
6 Was there a reconsideration of function allocation?	

Step 4: Define Task Requirements

Purpose

The purpose of this step is to ensure that operator tasks are properly analysed and the operator's requirements are identified.

Introduction

Currently, operator tasks are either not analysed or analysed in an unsystematic way. This leads to an incomplete understanding of the tasks and, therefore, to a control room that inadequately supports the operator. It is taken that the operator will adapt to the solution rather than the control room being designed to the operators needs. Tasks must be analysed to ensure that the finished control room will not make demands that operators are unable to meet.

Task analysis can be defined as the study of what operators must do in terms of actions and/or cognitive processing in order to carry out a function. Task analysis is a collective term that covers a number of techniques used to analyse operator tasks. For the purpose of this methodology it includes:

- Task Analysis
- Cognitive Task Analysis
- Physical Demands Analysis
- Workplace Analysis
- Human Machine Interface Analysis
- Human Computer Interaction Analysis
- Communications Analysis
- Workload Analysis
- Link Analysis

The aim of such analyses is to identify what tools and information is needed by the operator to perform the task. In addition Human Reliability Analysis and Human Factors HAZOPS can identify possible error points in the tasks and assess if theses errors are likely to be critical. The results of the analyses can be used for different purposes at different stages of the project and, therefore, the definition of task requirements is an iterative process.

In the early stages of the conceptual design phase, Hierarchical Task Analysis can be used to define tasks that will be carried out in the control room and map their interactions. It may also be used to set a framework for training and procedures development plans. In the detailed design phase, task analysis identifies each specific step needed to carry out a task, and the requirements relating to it, such as:

- display requirements,

- control requirements,
- communication requirements,
- knowledge and skill requirements, etc.

"A Guide to Task Analysis" (Kirwan and Ainsworth, 1992), describes: when to use certain techniques; the advantages and disadvantages of their use; resource requirements; and demonstrates the use of the different techniques through case studies. INFO-0605 (1995) is also very useful as it gives a description of the different types of analyses that can be used in the design process and the relationships between them.

Objectives

- Provide the bases for making design decisions, e.g., can system performance requirements be met by the proposed combination of equipment, software and personnel.
- Ensure that the task requirements do not exceed the operators' capabilities
- Provide input for procedures development and training programme development.
- Provide information on communication requirements
- Provide information for specifying the requirements for control centre layout, control room layouts, workstation layout and design.
- Provide information for specifying the requirements for displays and controls needed to carry out tasks.

Regulatory Requirements

The following regulations apply to this step:

- SAM Regulations, § 16, § 20 litera a and § 35 litera b
- NORSOK S-002 §§ 4.9.3-5 and § 5.2.2

Other Standards and Guidance

The following give additional guidance that is useful for this step:

- ISO/FDIS 11064-1 International Standards Organisation (1999a)
- NUREG–0711 U.S. Nuclear Regulatory Commission (1994)
- INFO-0605 Atomic Energy Control Board of Canada (1995)
- A Guide to Task Analysis. Kirwan and Ainsworth, (1992)

Information Sources for the Reviewer

- Project objectives related to control centre manning level
- List of tasks to be performed by the control room staff
- OER results pertaining to work-load and task requirements in existing control centre (in modification projects)

- Documentation of the method of task analysis used
- Documentation of the results of the task analyses

Review Guidance

1. Were appropriate human factors analyses conducted as part of the design process?

The type of analyses that are desirable will depend on the nature of the project and the scope of the work.

Note: the SAM Regulations, § 16 set requirements for systematic analyses to be carried out as a part of design work.

NORSOK S-002 § 4.9.4 sets requirements for an ergonomic job analysis to be carried out as a part of design work.

NORSOK S-002 § 4.9.5 sets requirements for a man-machine interface analysis to be carried out as a part of design work.

NORSOK S-002 Appendix I § I.3. refers to different types of analysis that can be used in this context.

2. Was the correct team assembled to perform the task analysis?

The team will depend on the precise task being considered and the type of analysis being carried out. For example, a workplace analysis should involve an ergonomist.

Note: the SAM Regulations, § 20, litera a sets competency requirements for personnel conducting safe job analysis

3. Were appropriate methods chosen?

A Guide to Task Analysis (Kirwan and Ainsworth, 1992) gives guidance on what methods are appropriate. A workload analysis, a physical analysis and a workstation analysis shall be carried out.

Note: the SAM Regulations, § 35 litera b and d sets requirements relating to adverse strain, working posture, arrangement of workplace and equipment, and requires that recognised ergonomic principles are followed.

4. Was the scope of the task analysis wide enough?

Representative tasks should be chosen from all types of the control room tasks, e.g., process monitoring and control, administrative tasks, checking, emergency management, etc. Information from the OER should also influence the scope of the task analysis. For example, tasks that were found to have a high rate of errors in previous designs should be included in the task analysis. In addition, a selection of tasks that were found to be without problems could be analysed to find what aspects of the design supported operator tasks so efficiently.

For modifications and upgrades the scope of the task analysis should include tasks involved in the upgrade, including those from new or changed functions identified in the function analysis and allocation, and their interaction with the rest of the installation.

5. Were tasks from the full range of operating conditions considered?

All operational states shall be represented during task analysis, i.e., normal, emergency, start-up, shut-down, etc.

6. Were safety critical tasks identified and a task analysis performed for each?

Each safety-critical tasks should have it's own specific task analysis performed.

Note: the SAM Regulations, § 20, litera a requires that a safe job analysis be carried out when work is complex or potentially hazardous

Note: NORSOK S-002 § 4.9.3 sets requirements for a detailed job safety analysis to be carried out as a part of design of work.

7. Were the results documented in a task description?

The results of the task analyses should be systematically recorded for future use in the project. The task descriptions should include:

- information gathering requirements, e.g., the type of information required (parameters, units, precision, accuracy) and it's source (alarm, displays, verbal or written communication).
- decision making requirements, e.g., evaluations to be performed, types of decisions to be made and their potential for error
- response requirements, e.g., action to be taken, frequency, body movements to be made, time available, etc.
- feedback requirement, e.g., is feedback needed to show the operator the action was successful
- task support requirements, e.g., procedures or job aids required, personal protective equipment,
- type of workload placed on the operator, i.e., mental or physical
- workspace factors, e.g., workspace envelope and environmental factors such as light, heat, noise, communication requirements, etc.,
- type of communication needed, i.e., human-machine, human-human, face to face, via communication systems
- skills and knowledge required to perform the task, and
- frequency of task performance.

8. Was the task analysis iterative?

The task analysis should begin in a limited way in the analysis phase and become more detailed over the design project. By the detailed design phase the information and control requirements should be detailed enough to make a detailed design specification for all aspects of the design within the scope of the project.

9. Did appropriate personnel participate in the task analysis?

End users and those currently involved in similar tasks have first-hand knowledge of task performance and are most qualified to say how the job is to be done in practice.

Note: the SAM Regulations' comments to § 35: Work Planning state that individual employee's evaluations and experience related to own work situation should be included as the basis for the planning and arrangement of the work.

10. For modifications and upgrades, were the results of previous analyses revised and updated?

The results of previous analyses should be modified in line with the results of the new analyses to ensure that information is up-to-date.

Table 4. Checklist for Define Task Requirements

Review Topic	**Comments on quality of evidence**
1 Were appropriate human factors analyses conducted as part of the design process?	
2 Was the correct team assembled to perform the task analysis?	
3 Were appropriate methods chosen?	
4 Was the scope of the task analysis wide enough?	
5 Were tasks from the full range of operating conditions considered?	
6 Were safety critical tasks identified and a task analysis performed for each?	
7 Were the results documented in a task description?	
8 Was the task analysis iterative?	
9 Did appropriate personnel participate in the task analysis?	
10 For modifications and upgrades, were the results of previous analyses revised and updated?	

Step 5: Job and Work Organisation

Purpose

The purpose of this step is to ensure that the tasks are assigned to each CCR operator in a systematic way that avoids individual operators from being over or under loaded.

Introduction

Once the tasks to be performed by operators have been identified, they must then be assigned to individuals so that each operator has a set of tasks that (s)he is responsible for. This assignment of tasks must consider the results of some of the analyses performed in Step 4: Definition of Task Requirements. In addition further analyses should be made to asses the effects of the task combinations on operator workload.

Currently staffing levels are often set before operator tasks are analyses or assigned. Then either little thought is given to whether the operator can realistically accomplish the tasks, or a great deal of resources can be spent trying to make the control room operable. The excessive demands placed on the operators by their workload leads to stress and mental fatigue. This is exemplified by the increasing amount of sick leave taken by CCR operators in some organisations. In either case, in situations when the workload may suddenly increases, e.g., emergencies, the operators can be left without the physical or psychological resources to deal with the situation. Therefore, staffing and job and work organisation need to be carefully considered. For the purpose of this document:

"Staffing" means the number of people required to run the control room and the knowledge and skills they need to possess; and

"Job and work organisation" means how the tasks are distributed and organised among those staff.

For both new control rooms and modifications, all operator tasks must be considered and, in the case of modifications and upgrades, possibly recombined and reassigned.

Issues for staffing and organisation can be considered broadly during the analysis phase and a tentative assignment of tasks can be made. However, once the detailed design is in place and the knowledge about equipment and layout becomes greater, the design must be assessed to ensure that: the tasks assigned to operators can be realistically accomplished; that the operators do not have conflicting requirements put on them by the tasks they are assigned; and that there is an optimal workload placed on the operator across operational modes. Examples of analyses that can be performed to ensure this are:

- Hierarchical Task Analysis;
- Timeline Analyses;
- Subjective Workload Assessment Technique;

- Demand-Resource Analysis;
- Cognitive Demands Analyses; etc.

Objectives

- Ensure that staffing is appropriate for all operational modes
- Ensure that operators have a workload that avoids stress or boredom
- Ensure there are enough operators to deal with emergency situations when they arise
- Ensure that operators can communicate effectively both within the control room and with those outside
- Ensure that the activities of the operators are co-ordinated

Regulatory Requirements

The following regulations and standards relate to this step:

- Working Environment Act §12 litera 1 and 2
- SAM Regulations §§ 16, 17, 25, 35 and 36
- Management Systems Regulations § 8 litera 2 d
- NORSOK S-002 §§ 4.5, 4.7 and 4.9.5.

Other Standards and Guidance

The following give additional guidance that is useful for this step:

- ISO/FDIS 11064-1 International Standards Organisation (1999a)
- NUREG–0711 U.S. Nuclear Regulatory Commission (1994)
- INFO-0605 Atomic Energy Control Board of Canada (1995)
- *Ergonomics in Process Control Rooms Part 2: Design Guideline.* International Instrument Users' Associations (1998)

Information Sources for the Reviewer

- List of tasks to be carried out by humans from Step 3
- Regulations and standards relating to this step
- Company policies on staffing and work organisation
- Information from OER from Step 1
- Results of analyses in Step 4

Review Guidance

1. Was staffing and job and work design an iterative process?

Tasks should be tentatively assigned and the resulting job should be analysed to ensure an appropriate workload. If the outcome of the analysis is unfavourable then the tasks assignment should be reconsidered.

Note: the SAM Regulations § 17 state the need for systematic mapping of the various working environment factors in relation to the employees work situation which may affect the employees physical and mental health and welfare. This will typically include a mapping of organisational and workload aspects.

Note: the SAM Regulations § 16 state that evaluations and analysis shall include a consideration of the planned organisation and manning of the activities, manning in order to perform defined tasks, task descriptions, etc.

2. Was a job assignment criteria checklist developed to help assign the tasks to a particular job?

Note: ISO/DIS 11064-1 recommends the development and use of job assignment criteria checklist and includes a list of typical criteria.

3. Were jobs organised so that all operators have a roughly equal workload?

A Guide to Task Analysis (Kirwan and Ainsworth, 1992) gives guidance on how to calculate a Workload Estimation for comparison of jobs

Note: the SAM Regulations, § 35 set requirements for a satisfactory workload for operators

4. Were jobs distributed so that operators have a variety of tasks?

The task loading should not result in one person getting all the boring or repetitive jobs. This is especially important where shifts are concerned because the number of low quality jobs will be multiplied by the number of shift teams there are. An appropriate function allocation should, however, minimised this possibility.

Note: the SAM Regulations § 35 litera a set requirements for a satisfactory workload

Note: the Working Environment Act §§ 12.1 and 12.2 sets requirements for planning of the working environment.

5. Was the operators' job satisfaction considered?

Job satisfaction can be assessed by using subjective measures such as questionnaires. In addition, feedback from the OER can be used as an indication of job satisfaction. **Note: ISO/FDIS 11064-1 recommends considering job satisfaction as a part of the job design process.**

Note: NORSOK S-002 §4.7 requires that a Psycho-social Analysis that includes an evaluation of job demands be performed using a systematic method.

6. Was rotation within the control room and between control room jobs and plant jobs been considered?

Rotation has several advantages:

- The variety of tasks increases and therefore boredom is less likely.
- The control room operators are familiar with the exact plant configuration and have a better understanding of the systems.
- If close monitoring is required, rotating operators maintains vigilance. Operators can only concentrate for about twenty minutes before there is a loss of performance.
- A pool of trained operators is available for higher workload conditions, for example, when there is upgrading or maintenance that requires much permit monitoring, JSAs and pre-work inspections. This may also be of use in some emergency situations but if the emergency affects the whole installation, plant operators may also have a full workload.

7. Were responsibilities allocated within the team?

The work organisation should result in clear definition of supervision responsibilities, lines of authority and communication hierarchies within the operator team.

Note: the Management Systems Regulations § 8 litera d set requirements for definition of roles and responsibilities.

8. Did the analyses include the full range of process conditions?

All process states must be analysed but emergency conditions should be given special attention as operators have additional tasks to perform and additional requirements for communications with, e.g., plant operators, emergency services, headquarters, etc.

Note: NORSOK S-002, §s 4.5 sets requirements for an organisation and manning study to be performed.

Note: NORSOK S-002, §s 4.9.5. states requirements for which system states job analyses shall include.

9. Were appropriate methods used in the analyses?

Appropriate methods and their use in setting staffing levels and assigning operator tasks can be found in 'A Guide to Task Analysis' (Kirwan and Ainsworth, 1992). We recommend that at minimum a time line analysis and workload analysis be carried out.

Note: the SAM Regulations § 17 set requirements for a systematic mapping of working environment factors that may affect the employees physical and mental health and welfare. This will typically include a mapping of organisational and workload aspects.

Note: NORSOK S-002 §4.7 requires that a Psycho-social Analysis that includes an evaluation of job demands be performed using a systematic method.

10. Did the analysis take into account information from the OER?

Include results of OER relating to staffing in preceding control rooms including information relating to operator workload, stress, difficulties in performing expected tasks, etc.

Note: the SAM Regulations §§ 16 and 25 require that the employees should be given opportunity to participate in development of work which is relevant to the arrangement and organisation of the work of the enterprise.

Note: the SAM Regulations in comments to § 17 include the use of operational and user experience in implementation of measures for improvement.

11. Did the analysis take into account information from the functional analysis and allocation?

For example, did the review team consider the training and experience needed by the operators to perform the functions allocated to them?

12. Did the analysis take into account information from the task analysis?

This includes:

- knowledge and skills needed to perform the tasks;
- the actions required from operators as found from the task analysis;
- the requirements for operators response time and workload; and
- requirements for communication and co-ordination.

13. Did the analysis take into account human reliability issues?

These include:

- the effect of staffing levels on the overall safety and reliability of the installation; and
- the effect of staffing levels and the co-ordination of individual operator roles, both inside and outside the control room, on critical actions.

14. Did the analysis take into account the interaction between staffing and workstation design?

This means the interaction of staffing and the positioning of equipment, e.g.,

- the physical layout of equipment or controls and displays;
- availability of information from individual operator workstations;
- controls and displays that are shared, such as large screens, printers, etc.

Note: the SAM Regulations § 35 set requirements for planning and organisation of display screen workstations.

15. Did the analysis take into account the effects of procedures on staffing?

This means:

- actions the operators are required to perform as part of following procedures, especially where the actions of two operators must be co-ordinated.
- the skills and knowledge required of the operators by procedures.

16. Did the analysis take into account the interaction between operators?

This includes:

- interaction, co-ordination and communication between operators that is required for diagnosis planning and control activities.
- interaction and communication between personnel for administrative tasks, communications and reporting activities, e.g., filling in work permits, pre-job inspections, etc.

17. Did the analysis take into account the availability of operators?

Availability should take into account:

- other activities operators may be required to perform outside the control room, e.g., pre-job inspections, JSAs, assisting in incident investigations or fulfilling safety representative responsibilities, training, etc.
- additional personnel needed to cover for staff absent for holidays or sickness.

18. Were shiftwork effects considered when designing and organising work patterns?

"Making Shiftwork Tolerable" (Monk and Folkard, 1992) provides good guidance for organisation of shift teams.

19. Were the results of the job and work organisation passed forward?

The results should be included in requirements for operating procedures, training programmes and design specifications for the control room.

Table 5. Checklist for Job and Work Organisation

Review Topic	Comments on quality of evidence
1 Was staffing and job and work design an iterative process?	
2 Was a job assignment criteria checklist developed to help assign the tasks to a particular job?	
3 Were jobs organised so that all operators have a roughly equal workload?	
4 Were jobs distributed so that operators have a variety of tasks?	
5 Was the operators' job satisfaction considered?	
6 Was rotation within the control room and between control room jobs and plant jobs been considered?	
7 Were responsibilities allocated within the team?	
8 Did the analyses include the full range of process conditions?	
9 Were appropriate methods used in the analyses?	
10 Did the analysis take into account information from the OER?	
11 Did the analysis take into account information from the functional analysis and allocation?	
12 Did the analysis take into account information from the task analysis?	
13 Did the analysis take into account human reliability issues?	
14 Did the analysis take into account the interaction between staffing and workstation design?	
15 Did the analysis take into account the effects of procedures on staffing?	
16 Did the analysis take into account the interaction	

between operators?	

17 Did the analysis take into account the availability of operators?	
18 Were shiftwork effects considered when designing and organising work patterns?	
19 Were the results of the job and work organisation passed forward?	

Step 6: Verification and Validation of Phase B

Purpose

The purpose of an intermediate V&V at this step is to check and approve as a whole the allocations and assignments made in the preceding steps of phase B: function allocations, job and organisation designs, and task requirements. To ensure a safe and functional control centre, any conflicts between these preliminary design steps should be resolved before carrying out the conceptual design.

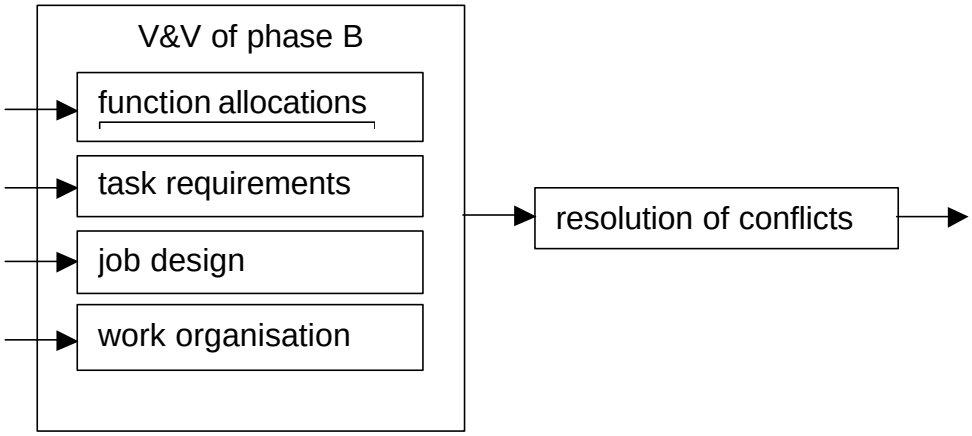

Figure 6.1. Purpose of Step 6, Verification and Validation of Phase B.

Introduction

An intermediate V&V of function and task allocations, task requirements, job assignments and work organisations (i.e., the products of Step 3, 4 and 5) should be performed before beginning conceptual design. This is because it is possible at this stage that particular allocations and assignments may be in conflict, either with one another, or with other, independent job definitions and classifications (outside the project). The emphasis should be on looking *as a whole* at individual allocations and assignments made in Steps 3, 4 and 5 (ISO/FDIS 11064–1, p.15).

The review guidance section below targets specific issues and problems for phase B of a design. Note that it is not the purpose of the review team to redesign the control room. The purpose is to assess the work so far.

Objectives

The objectives of an intermediate review step before starting conceptual design in phase C are for an internal review team to:

- Examine *as a whole* the allocations and assignments in Steps 3, 4 and 5:
  - function allocations;

  - task requirements;
  - job design; and
  - work organisation; in order to
- Resolve conflicts; issue revised statements and requirements, if necessary. Resolution will need to happen in conjunction with the design team.

Regulatory Requirements

- Safety Regulations §19

Other Standards and Guidance

- ISO/FDIS 11064–1 International Standards Organisation (1999a)
- IEC 964, International Electrotechnical Commission (1989)

Information Sources for the Reviewer

- *Results of function allocations from Step 3* — sets of functions to be done by people, sets of functions to be done by machines, sets of interactions between people and machines.
- *Results of the definition of task requirements in Step 4* — information-gathering requirements, decision-making requirements, response requirements, feedback requirement, task support requirements, type of workload placed on the CCR operators, workspace factors, type of communication needed, etc.
- *Results of the design of jobs and work organisation in Step 5* — authority and responsibilities, teams, working cultures, union agreements, regulations, need for physical nearness, intercommunication needs, etc. These results should include job specifications for each CCR operator.

Review Guidance

1. Were documents from the previous design steps available to the review team?

Step 3 produced sets of functions to be performed by people and machines, and interactions between the two. Step 4 produced task descriptions and requirements for task performance placed on operations personnel. Step 5 produced a proposal for assignments of jobs to each CCR operator and their work organisation.

2. Was the function assignment verified and validated?

The review team should verify the completeness of the function assignment. That is to say, there should be a check that all identified functions have been allocated in some way.

The review team should check that the function assignment is correct, that it makes best use of people and machines. There should also be a check that the assignments are realistic. Often, this is a first estimation whether the required functions can be performed in the time available for them, especially if there is a safety concern (IEC 964, 1989, p.83). Later, this can be made more precise in detailed design and tested in V&V of detailed design (Step 10). The static

function analysis from Step 2 and 3 does not necessarily make clear how a series of functions are carried out dynamically under a specific event.

3. Were the task requirements verified and validated?

The review team, having an independent viewpoint and composition from the design team, should check that the work describing task requirements is complete and realistic.

4. Was the design of jobs and their organisation verified and validated?

Verification of job design should include checks against the regulations, standards and guidelines that the project has already set for itself in earlier steps. Step 1, for example, advises that a list of standards, guidelines and regulations for the project is drawn up. Issues that the review team should consider in validation include:

- Can the proposed size of operating crew control the plant and installation effectively in various operating scenarios?
- Can the CCR operators communicate effectively with each other and co-ordinate actions in operating scenarios?
- Can the CCR operators maintain awareness of plant and installation conditions and the results of the actions of themselves and others in operating scenarios?

5. Were conflicts from previous steps resolved?

The information provided by the previous steps in the analysis and definition stage should allow the review team to discover any conflicts between requirements, suggested task allocations, job designs, etc. The review team in co-operation with the design team needs to state how any conflicts are to be resolved.

Resolutions of any conflicts in the design so far are needed before conceptual design in phase C starts. For instance, it is not possible to make preliminary arrangements of equipment for each CCR operator until it is resolved which functions and tasks are allocated to each OS. Job and work organisation in general interacts with, for example, layout design.

Table 6. Checklist for Verification and Validation of Phase B.

Review Topic	**Comments on quality of evidence**
1 Were documents from the previous design steps available to the review team?	
2 Was the function assignment verified and validated?	
3 Were the task requirements verified and validated?	
4 Was the design of jobs and their organisation verified and validated?	
5 Were conflicts from previous steps resolved?	

Step 7: Conceptual Design Framework for the Control Centre

Purpose

This step integrates the results of previous steps and produces one or several design concepts and preliminary specifications. These cover all aspects of the control centre that will be changed by the project. The step itself is not so much a human factors matter as a matter of design management. This step should therefore be read with phase A, Step 0: Human Factors Progranmme Management.

Introduction

The control centre is a combination of control rooms, control suites and control stations that are functionally related and all on the same site. Whether a new control centre is being built or an upgrade is being considered, the conceptual design is the stage where potential conflicts between all design requirements (not just human factors issues) begin to be resolved. (Requirements for work organisation and for function, task and job design are resolved in Step 6.)

The design team commonly has to satisfy many requirements that sometimes pull in different directions, such as multiple clients or contractors, conflicting objectives, different technologies, ambitious schedules and first-time applications. Performing the steps leading up to and including conceptual design can make it easier to deal with the complexities of the design process.

The results of the previous steps should be used (taking a point of view of integrated system performance) to produce one or more design concepts and preliminary specifications. These should cover all aspects of the control centre's functions and physical characteristics that could be affected. For example, the results of job design and work organisation (Step 5) can form a basis for deciding workspace requirements (ISO/FDIS 11064–1, p.16).

Objectives

The purpose of this step, and the whole of phase C, is to develop at least one possible design that satisfies the requirements established in phase A and B. According to ISO/FDIS 11064–1, p.16, this step produces:

- *conceptual design specifications* — including preliminary layouts, and:
  - an account of significant design constraints, such as budget, location, safety, styling, redundancy, materials, etc, that affect human factors;
  - a statement of the human factors and related standards that the project will be designed towards, e.g., applicable regulations, standards, codes and usual practices in the industry (this may be identical with the one produced in Step 1, or a revised or more detailed list);

- estimates of resources needed to complete human factors design specifications at least, and, if required, estimates of the cost of the complete project; and
- operational links among functional areas.

Much of this information is available from previous steps and will be part of the larger picture in any project.

The conceptual design process could result in more than one candidate design idea. These ideas, if offered as alternatives at this stage, can be individually examined and combined for a conceptual design.

Regulatory Requirements

- Safety Regulations, §§ 9, 12
- Management Systems Regulations, § 8.2 litera b, c and e
- Safety And Communications Systems Regulations, § 16 litera c
- SAM Regulations §§ 13, 14, 15, 25, 35
- NORSOK S-002 § 4

Other Standards and Guidance

ISO/FDIS 11064–1 International Standards Organisation (1999a)

Information Sources for the Reviewer

- Outputs of phase A
- Outputs of phase B
- Regulatory guides, standards and other formal documents
- Design constraints documents, such as budgets, time requirements, and safety

Review Guidance

1. Were there suitable methods and actions in this step?

ISO/FDIS 11064–1 p.17 defines the methods and actions associated with Step 7 to be:

- define design policy (e.g., device selection policy);
- define design criteria (e.g., ones that conform to user requirements and regulatory guides, standards and other formal requirements); and
- develop design specifications.

Any restrictive policies and constraints should be stated if they have not already been done so in phase A (e.g., preferred equipment vendors, system designs). It is important that all applicable guidelines, standards and regulations are stated and included in the preliminary specifications. (These should already have been called into the project as part of Step 1.)

Much of this work will already have been done in phase A. If this work exists, then there is no need to repeat it here. The purpose of this step is to make a record of the aspirations of the project and the conceptual design so far, to give a basis for the following design work. A clear statement at this stage also helps the checking process later, such as the V&V in Step 10.

Note: the Safety Regulations, § 12, refer to specific requirements relating to safety.

Note: the SAM Regulations, §13, 14 and 15, refer to the setting up of working environment objectives and a working environment programme in the design of installations.

Note: ISO/FDIS 11064–1 contains a phase entitled 'conceptual design' that includes steps for design and approval of the conceptual framework for the control centre.

2. Was the conceptual design comprehensive?

Conceptual design items for the preliminary design should include all those aspects affected by the project. That is to say, everything that will be changed by a project needs to be included in conceptual design. Other design steps, such as Step 2, should already have identified these aspects.

3. Was each affected human factors aspect considered?

The affected aspects (areas of change) will depend on the size and scope of the project and could include any of the topics that will later need to be covered in phase D, in particular in sections within Step 9. Typical things that are affected by an upgrade of new design are:

- *space allocations* — e.g., changed areas for each task, reallocations of task-areas to rooms in the control centre such as bulky cabinets and relays replaced by more compact digital technology;
- *functional links* — e.g., changed communication, shared displays, possibilities to combine task areas;
- *control suite arrangement* — e.g., changed layout for the whole control centre, including relationships between task-areas, accessibility, environmental constraints, requirements to integrate several control suites into one facility;
- *control room layout* — e.g., changed layout for the control room due to staffing or equipment changes, new functions allocated to the CCR;
- *workstation layout and dimensions* — e.g., changed requirements for display space, desks, communication equipment, body space, sightlines to panels, large screens, etc;
- *displays and controls* — e.g., new aids such as PCs introduced to the workplace, new display technologies such as large screens, shared displays;
- *information and data flows* — e.g., communications with other staff, print-outs, telecommunications;
- *special security and access controls* — e.g., access to the control suite, control of work permits;
- *environmental conditions* — e.g., changed heat, vibration and noise conditions due to introduction of new equipment, requirements on lighting due to display technologies;
- *operation and management systems* — e.g., management information duties, new requirements for management reporting and logging based on possibilities given by new technology and automation, work orders, work permit handling;

- *communication and information links* — e.g., UHF/VHF radio, mobile telephony, new links to remote facilities, links offshore-onshore newly allocated to the control centre.

4. Was there allowance for constraints such as functional isolation and separation?

Although this is not primarily a human factors requirement, it has implications for conceptual design. The human factors members of the design team therefore need to know about separation and safety issues that affect the design and layout. Documentation of the conceptual design should make clear where compromises have been made due to these requirements.

Note: the Explosion and Fire Protection Regulations, such as § 17, contain requirements relating to placement of fire divisions and protection of main areas, which includes the control centre.

Note: the Explosion And Fire Protection Regulations, § 16, refers to effective operation and maintenance, which may have implications for the placement of the control centre.

Note: the Safety and Communications Systems Regulations, such as § 16, require that certain systems used by the control centre remain operational during dimensioning accidental events.

5. Were alternative ideas individually appraised?

In many instances, it may be desirable to generate several design alternatives. If this is the case, then these should be individually examined at this stage. There may be a potential to combine ideas into an improved conceptual design.

6. Was there a clear output from the conceptual design?

The output of the step will be input for both a review of the conceptual design in Step 8 and for the detailed design. The output needs to be specific and clear enough for the design team to perform Step 8. For instance, if applicable regulations and design standards are not stated (or confirmed from Step 1), it will not be possible to decide whether the conceptual design actually meets the design standards. (That is to say, it will not be possible to verify the conceptual design.)

Projects will vary in the degree to which detailed design aspects are affected. Not all projects will need to investigate or specify all areas exhaustively. The project record should include any decisions made at the conceptual design stage about the work needed (or not needed) in these areas.

Table 7. Checklist for Conceptual Design Framework

Review Topic	**Comments on quality of evidence**
1 Were there suitable methods and actions in this step?	
2 Was the conceptual design comprehensive?	
3 Was each affected human factors aspect considered?	
4 Was there allowance for constraints such as functional isolation and separation?	
5 Were alternative ideas individually appraised?	
6 Was there a clear output from the conceptual design?	

Step 8: Conceptual Design Approval

Purpose

A formal review of the conceptual design is an opportunity for checking the proposed design before starting detailed design. It also lets (or makes) the project team develop a common understanding for a way forward for the design. Thirdly, it lets management see the proposals and decide whether to support them before committing major resources. Fourthly, it reduces the risk that the project team must make expensive changes later in the project.

Introduction

This step is an important milestone in a project. It concludes all the preparatory work in phases A, B and C. Phase B provided preliminary analyses and definitions. Phase C, Step 7, gave preliminary design specifications. In this step, the design team seeks approval for its proposals from the users, owners and maintainers. If the previous work has been done well, and this step is completed satisfactorily, then detailed design work can start with the minimum risk of major functional revisions and physical changes. The step itself, like step 7 immediately before it, is not so much a human factors matter as a matter of management of human factors work, and the design project as a whole.

Objectives

Step 8 has several goals:

- to check design concepts and preliminary specifications;
- to check that the conceptual design continues to satisfy the project's functional requirements and remains in compliance with applicable regulations, standards, guidelines and policies;
- to define a common, agreed design concept for the benefit of the design team at later stages;
- to provide a milestone with a visible product that can be shown to others outside the design team, such as managers who control funding for the project, external supervisory agencies, such as the NPD, and users;
- to minimise the need for basic design changes and shifts in strategy later in the project, when corrections are more expensive.

Phase C needs to have a visible result, namely a conceptual design specification checked and agreed at least to the level of the project team concerned. Optionally, there can be supporting products, such as physical mock-ups, computer visualisations or virtual reality models. Such products are, incidentally, very useful at later stages of the project.

Regulatory Requirements

- Safety Regulations § 19

Other Standards and Guidance

- ISO/FDIS 11064–1 International Standards Organisation (1999a)

Information Sources for the Reviewer

- Results of the conceptual design framework from Step 7 in particular, and all previous design information in general
- Results of the verification and validation from Step 6

Review Guidance

1. Were the review and approval of conceptual design independent (to some degree) from the conceptual design itself?

It is difficult for a team that understands its own product to review it neutrally, simply because it knows too much about the product. In addition, the team is likely to feel defensive about suggestions that there are problems or faults. For these reasons, it is both advisable (and required by regulations for some aspects) that the review is independent from the design team.

Note: the Safety Regulations, § 19, refer to verification of specifications for safety.

2. Were the review and approval done with suitable personnel and methods?

ISO/FDIS 11064–1 (1999) suggests several methods or actions that can be used in the approval process:

- *Scenario 'talk-through'*.
- *Scenario 'walk-through'* — a 'walk-through, talk-through' approach uses experts who give a commentary while acting out scenarios. For example, control and displays can be pointed to at the times they would be used, whilst the actions are explained verbally.
- *Interface simulations* — e.g., physical mock-ups, computer visualisations or virtual reality models.
- *Audits* — e.g., of compliance with standards, policies and regulations, checks against the objectives and standards that the project team set for itself.
- *CRIOP*— a tabletop analysis of the design to this point.

Note: ISO/FDIS 11064–1 contains a phase entitled 'conceptual design', which includes steps for design and approval of the conceptual framework for the control centre.

3. Was there a check that the design continued to be acceptable?

Step 6 provided a verification and validation of Steps 3 (function allocation), 4 (task requirements) and 5 (job and work organisation). It is possible that the conceptual design in Step 7 removed or changed some of the basis for the verification and validation. Accordingly, there should be a check that the specifications from Step 7 "continue to satisfy the project's

functional requirements and remain in compliance with all applicable standards, guidelines and policies." (ISO/FDIS 11064-1, p.17).

Note that it is not suggested that work in Step 6 is repeated unnecessarily.

4. Was there documentation of the process and results of the design review and approval?

All relevant issues and resolutions of any conflicts should be reviewed and documented. It should be clear which design alternatives are approved and chosen for continuation into detailed design. This is a prerequisite for detailed design, which follows in phase D.

5. Was there an agreed design concept that was common to all parties?

The documentation should make clear whether all parties involved in the design have accepted and have an understanding in common of the proposed design. Parties include the owners and operating company, the users and CCR operators, and the maintainers of the systems being built or upgraded.

Table 8. Checklist for Conceptual Design Approval

Review Topic	**Comments on quality of evidence**
1 Were the review and approval of conceptual design independent (to some degree) from the conceptual design itself?	
2 Were the review and approval done with suitable personnel and methods?	
3 Was there a check that the design continued to be acceptable?	
4 Was there documentation of the process and results of the design review and approval?	
5 Was there an agreed design concept that was common to all parties?	

Step 9.1: Control Suite Arrangement

Purpose

The main objective of Step 9.1 is to develop detailed design specifications for control suite arrangement. The arrangement refers to the various rooms in a control suite.

Introduction

NORSOK I-CR-004 defines a control centre as the assembly of technical and operational rooms and systems that are required for control, monitoring and supervision of an offshore installation. This step is concerned with the functional areas making up the control suite, the space requirements for them and the suitability of the planned location (ISO/FDIS 11064–1). 'Control suite arrangement' brings several issues together, all of which can have an influence on how well the final design works. Issues affecting the final 'assembly' referred to in NORSOK I-CR-004 include: communication, traffic and routing, entrances and exits, environmental conditions, cleaning, maintenance, visitors and access control, and supporting functions (ISO/DIS 11064–2). Clearly, many areas of expertise need to be represented. In addition to the CCR itself, 'Control Suite Arrangement' also covers associated rooms and services.

Objectives

Several activities are required of the design team so that the main objective can be reached—to develop design specifications for control suite arrangement. These are (ISO/FDIS 11064-1):

- call in relevant standards, etc., (listed in Step 1),
- verify the availability of necessary utilities,
- confirm suitability of the planned site,
- confirm the functional areas making up the control suite, from phase C,
- estimate the space requirements for each functional area.

Regulatory Requirements

- NORSOK I-CR-004
- NORSOK C-001

Other Standards and Guidance

Parts of several international standards are relevant:

- NORSOK I-002 § 6.4.1
- ISO/FDIS 11064–1. International Standards Organisation (1999a) Step 9A

- ISO/DIS 11064–2 International Standards Organisation (1999b)
- *Ergonomics in Process Control Rooms Part 2: Design Guideline.* International Instrument Users' Associations (1998) § 5
- CRIOP. SINTEF. (1990)
- Menneske-maskin forhold i kontrollrom: Ergonomiske analyser og retningslinjer. Norwegian Petroleum Directorate

Information Sources for the Reviewer

- Information from phase C, particularly information on the operational links between functional areas, and information on the preliminary control suite layout
- Information on task design from Step 4
- Information on job and organisation design from Step 5
- Current copies of regulations, standards, building codes, policies, etc., and the standards that the project has set itself in Step 1

Review Guidance

The two most thorough sources for guidance on Control Suite Arrangement are ISO/DIS 11064–2: *Principles of Control Suite Arrangement,* and International Instrument Users' Associations *Ergonomics in Process Control Rooms Part 2: Design Guideline*. (1998), particularly chapter 5 on control centre and control room layout. Appendix 10A contains some guidance for control suite arrangement.

1. Was the correct team chosen for developing the detailed design of control suite arrangement?

The correct team should consist of people with a mix of appropriate skills. For example, the team could include members from petroleum engineering, architectural design and civil engineering, systems analysis, I&C, computer systems and software engineering, ergonomics; human factors engineering, and operating experience and training.

The details of control suite arrangement may interact with other details of the site or installation plans. Many factors will influence the design, such as economic factors, size and shape of the surrounding areas, and existing parts of the installation. The team's composition needs to reflect this.

2. Was all necessary input material gathered that relates to control suite arrangement?

Appropriate materials are:

- list of requirements from relevant standards and regulations,
- list of goals and requirements from phase A
- list of requirements from analyses in phase B
- conceptual design specification from phase C.

The general layout of an installation, the production facilities, process descriptions and operating principles are important background information

3. Was the detailed design of control suite arrangement planned appropriately?

ISO/DIS 11064–2 give guidance for planning the arrangement:

- location of control room suite
- task zones in the control room suite, and
- design of the control room suite.

In addition, several factors are listed that may influence the design, which should incorporated and evaluated in the planning of detailed design

- communication — verbal and visual requirements
- entrances, traffic, routing and visitors
- environmental conditions — e.g., materials, potential for disturbances (see also Step 9.5)
- cleaning, maintenance, access for equipment
- supporting information

Note: NORSOK I–CR–004 refers to limitations on personnel traffic in the control room.

Note: NORSOK I–002 § 6.4.1 refers to the number of operator stations in the CCR.

Note: NORSOK C–001 § 6.5 refers to the placement of the CCR relative to other facilities.

4. Was the detailed design of control suite arrangement documented appropriately?

There should be a record of the detailed design process, including:

- input materials;
- the team members;
- the schedule;
- methods used; and
- the design results, including deviations, non-conformities, assessments against criteria, resolutions and resulting changes.

Typically, the control suite arrangement is fixed at the start of the detailed design phase. The results of this step therefore need to be documented so that other steps, for instance, 9.3 and 9.4, can proceed.

Note: NORSOK C-001 contains requirements relating to the placement relative to the CCR of :

- **the emergency room**
- **the work permit and personnel control station**
- **maritime control functions**
- **office facilities, the process supervisor's office and the printer room, the central equipment room and the telecom equipment room.**

5. Were any conflicts in requirements for arrangement resolved?

Design documentation needs to show for identified discrepancies that:

- resolutions have been developed and documented;
- non-conformities have been identified;
- resolutions have been implemented; and
- resolutions have been checked for potential side-effects.

For example, documentation should record where compromises have been made so as to fit in with an existing arrangement of control rooms within a suite.

It is also important that the design is documented for V&V reasons (Step 10). Many compromises are typically made during detailed design of a control suite. Each of these should be documented to enable V&V.

6. Have the review questions from CRIOP Part 1, section 1 (layout) been answered appropriately?

Table 9.1. Checklist for Control Suite Arrangement.

Review Topic	**Comments on quality of evidence**
1 Was the correct team chosen for developing the detailed design of control suite arrangement?	
2 Was all necessary input material gathered that relates to control suite arrangement?	
3 Was the detailed design of control suite arrangement planned appropriately?	
4 Was the detailed design of control suite arrangement documented appropriately?	
5 Were any conflicts in requirements for arrangement resolved?	
6 Have the review questions from CRIOP Part 1, section 1 (layout) been answered appropriately?	

Step 9.2: Control Room Layout

Purpose

The purpose of this step is to develop appropriate design specifications for the control room layout.

Introduction

This step addresses the detailed design of the CCR layout. The design specifications are used to estimate and plan the construction of the CCR and need to be sufficiently detailed that the layout can be built.

The control room is the focus for operation of the installation with limited interaction between the operators and the external plant. Therefore, the control room must provide the operators with all the information they need to achieve operational and safety goals without discomfort, stress or physical hazard. There is good guidance generally available for CCR design and usually ergonomists are involved in the design work. Therefore, control rooms are improving in terms of their ergonomic aspects. A major problem, however, is that there is a lack of analysis of operators' tasks that have an influence on layout. The results from the analyses in Phase B will identify the tasks to be carried out in the control room and will result in a layout that is compatible with both the sequences of operator activities when controlling the installation, and the standards that relate to control room design.

The issue of CCR layout is generally well covered by existing standards and guidelines, and other than referring to these, this step is relatively brief.

Objectives

- Ensure the usable space has been determined
- Ensure the furniture and equipment to be accommodated in the control room space has been identified
- Ensure the operational links have been determine
- Ensure the circulation requirements have been specified
- Ensure the maintenance access requirements have been specified

Regulatory Requirements

- The SAM Regulations § 32
- The SAM Regulations, § 35 litera b and d
- NORSOK C-001 §§ 6.4 and 6.5
- NORSOK S-002 § 4.9.5
- NORSOK I-CR-004 § 5.2

Other Standards and Guidance

- ISO/FDIS 11064–1. International Standards Organisation (1999a)
- ISO/FDIS 11064–3. International Standards Organisation (1999b)
- *Ergonomics in Process Control Rooms Part 2: Design Guideline.* International Instrument Users' Associations (1998)
- Menneske-maskin forhold i kontrollrom: Ergonomiske analyser og retningslinjer. Norwegian Petroleum Directorate.
- CRIOP. SINTEF (1990)

Information Sources for the Reviewer

- Information from phase B and C, particularly information on the operational links between functional areas, and information on the preliminary control room layout
- Information on task design from Step 4
- Information on job and organisation design from Step 5
- Current copies of regulations, standards, building codes, policies, etc. and the standards that the project has set itself
- Detailed design specifications for control room layout

Review Guidance

The two most thorough sources for guidance on Control Room Layout are: ISO/DIS 11064-3: *Control Room Layout;* and International Instrument Users' Associations *Ergonomics in Process Control Rooms Part 2: Design Guideline*. (1998), particularly chapter 5 on control centre and control room layout.

1. **Was the correct team chosen for developing the detailed design for control room layout?**

   The correct team should consist of people with a mix of appropriate skills but should include ergonomists, human factors experts and experienced operators.

2. **Was the appropriate input material gathered as a basis for the detailed specification for control room layout?**

   Appropriate materials are:

   - list of requirements relating to control room layout from relevant standards and regulations,
   - list of goals and requirements relating to control room layout from phase A,
   - list of requirements relating to control room layout from analyses in phase B,
   - conceptual design specification from phase C.

   Note: NORSOK C-001 §§ 6.4and 6.5 contains architectural and engineering and functional requirements relating to control room layout.

   Note: NORSOK S-002 § 4.9.5 requires that layout design is based on task analysis.

Note: NORSOK I-CR-004 § 5.2 sets requirements for CCR layout and suggest that the design team "consider use of 3D modelling in making the CCR layout."

Note: NORSOK C-001 § 6.4 contains requirements for paper and document centre.

Note: ISO/FDIS 11064–3 gives general principles for CCR layout.

3. Was the detailed design planned appropriately?

Appropriate planning includes:

- list the CCR tasks;
- specify task areas;
- identify possibilities to combine task areas; and
- develop layout proposals.

Note: ISO/FDIS 11064–3 gives guidance on planning.

Note: Ergonomics in Process Control Rooms gives guidance on planning.

4. Was an appropriate process and method used to develop the detailed design specification?

An appropriate method would be to build a mock-up or VR model to test out the design specifications, to ensure they are appropriate, and to identify conflicts and discrepancies in the design.

Note: NORSOK I-CR-004 § 5.2 suggest that the design team use of 3D modelling in making the CCR layout.

5. Were the conflicts resolved?

This means that for identified discrepancies:

- resolutions have been developed and documented;
- non-conformities have been identified;
- resolutions have been implemented; and
- resolutions have been checked for potential side effects.

6. Was the detailed design documented appropriately?

There should be a record of the detailed design process, including:

- input materials;
- the schedule;
- methods used; and
- the design results, including deviations, non-conformities, and assessments against criteria, resolutions and resulting changes.

7. Does the layout conform to ergonomic principles?

Information from the standards and guidelines can be used to review the design fully.

Note: the SAM Regulations, § 35 litera b and d sets requirements relating to adverse strain, working posture, arrangement of workplace and equipment, and requires that recognised ergonomic principles are followed.

8. Has a CRIOP Phase 1: General Analysis of Layout been conducted?

An evaluation using this part of CRIOP will help to establish the appropriateness of the design.

Table 9.2. Checklist for Control Room Layout

Review Topic	**Comments on quality of evidence**
1 Was the correct team chosen for developing the detailed design for control room layout?	
2 Were the appropriate input material gathered as a basis for the detailed specification for control room layout?	
3 Was the detailed design planned appropriately?	
4 Was an appropriate process and method used to develop the detailed design specification?	
5 Were the conflicts resolved?	
6 Was the detailed design documented appropriately?	
7 Does the layout conform to ergonomic principles?	
8 Has a CRIOP Phase 1: General Analysis of Layout been conducted Does the layout conform to ergonomic principles?	

Step 9.3: Workstation Layout and Dimensions

Purpose

The main objective of this design step is to provide detailed design specifications for layout and dimensions of operator stations that are acceptable from the perspectives of performance, safety and the working environment.

Introduction

The general approach is to design the workstations to meet performance, safety and working environment requirements. The design team needs to 'read into' the project all the relevant information about their user population. Lists of relevant design standards, etc., were identified in Step 1. Detailed workstation design is preceded by the preparatory work in phases A and B, where tasks and functions are analysed and preliminary working arrangements are made. Detailed workstation design will also be influenced by particular technological choices made, such as the types of displays, support systems, and communications equipment.

Objectives

Several activities are required from the design team so that the main objective can be reached—to develop design specifications for workstation layout and dimensions before starting construction work. These are (from ISO/FDIS 11064-1):

- *analyse and clarify the tasks* to be done at each workstation;
- *identify the necessary functional elements* of each workstation, such as displays, controls, working space, communications equipment; and
- *develop detailed specifications* — i.e., workstation layouts and dimensions.

Regulatory Requirements

- NORSOK I-004 § 5.2.2
- SAM Regulations §§ 35–37
- NORSOK S–002 Annex B

Other Standards and Guidance

- NORSOK I-002
- ISO/FDIS 11064–1 International Standards Organisation (1999a) Step 9C
- ISO/DIS 11064–4 International Standards Organisation (1999d)
- *Ergonomics in Process Control Rooms Part 2: Design Guideline.* International Instrument Users' Associations (1998) § 6

- CRIOP. SINTEF. (1990)
- Menneske-maskin forhold i kontrollrom: Ergonomiske analyser og retningslinjer. Norwegian Petroleum Directorate

Information Sources for the Reviewer

- Information from phase C, particularly information on the operational links between functional areas, and information on the preliminary control suite layout
- Information on task description and design from Step 4
- Information on job and organisation design from Step 5
- Current copies of regulations, standards, building codes, policies, etc., and the standards that the project has set itself (listed in Step 1)
- Specifications for control suite arrangement from Step 9.1
- Specifications for control room layout from Step 9.2

Review Guidance

The two most thorough sources for guidance on Workstation Layout and Dimensions are ISO/DIS 11064-4: *Workstations Layout and Dimensions*, and International Instrument Users' Associations *Ergonomics in Process Control Rooms Part 2: Design Guideline*, (1998), particularly chapter 6 on workplace layout.

1. Was the correct team chosen for developing workstation layout and dimensions?

The correct team should consist of people with a mix of appropriate skills. For example, the team could include members from petroleum engineering, architectural design and civil engineering, systems analysis, I&C, computer systems and software engineering, ergonomics; human factors engineering, and operating experience and training.

Since this is a detailed technical subject, members of the design team will need to be familiar with design standards and data listed in Step 1 (for example, body dimensions of the relevant user population). The team will also need to be aware of the practical alternatives for furnishing, desk design, supply, etc.

2. Was all necessary input material gathered for the detailed design of workstation layout and dimensions?

Appropriate materials are:

- list of requirements from relevant standards and regulations (Step 1),
- list of goals and requirements from phase A
- list of requirements from analyses in phase B
- conceptual design specification from phase C.

The design team needs to know all the task requirements for each workstation. They take this from phase C. For instance, they need to know the number of users and the communication links to other workstations. They need to know the instrumentation for each workstation, such as VDU displays and communications equipment.

Note: ISO/DIS 11064–4 gives specific principles, guidelines and requirements for workstation layout and dimensions.

3. Was the detailed design of workstation layout and dimensions planned appropriately?

ISO/FDIS 11064–4 gives a procedure for workstation design:

- List all requirements from phase C for each workstation
- List instrumentation for each workstation
- Determine the expected user population (see also Step 1)
- Design the horizontal layout
- Design vertical cross-sections in several planes
- Review the design with users

Note: the SAM Regulations §§ 37-37 set requirements for design work related to workstation layout and dimensions that is more directed towards health and safety of operators.

NORSOK I–002 refers to information presentation on display screens consistent with function.

4. Were the detailed dimensions and layouts of each workstation documented appropriately?

There should be a record of the detailed design process, including:

- input materials;
- the team members;
- the schedule;
- methods used; and
- the design results, including deviations, non-conformities, assessments against criteria, resolutions and resulting changes.

The documentation should cover: the arrangement in the horizontal plane of equipment at each workstation; cross-sections of workstations at several locations in several viewing directions. Design solutions, compromises and tests with users should be documented.

Note: NORSOK I-004 § 5.2.2 refers to requirements for seated operation, work postures, number of workstations, etc.

Note: NORSOK S-002 annex B gives advice with regards to detailed horizontal and vertical dimensions on control desks, etc.

5. Were the conflicts resolved?

Design documentation needs to show for identified discrepancies that:

- resolutions have been developed and documented;
- non-conformities have been identified;
- resolutions have been implemented; and

- resolutions have been checked for potential side-effects.

Note that the detailed design, the resolution of conflicts, etc., may have implications for other parts of the project outside human factors. For example, layout work may lead to suggestions for choices of certain display technologies, such as compact LCD monitors or shared overview displays.

Note: NORSOK I-004 § 5.2.2 refers to both performance and safety objectives for the control suite.

6. Have the review questions from CRIOP Part 1, section 1 (layout) been answered appropriately?

This section of CRIOP gives a review of the control centre layout, workstations and dimensioning.

Table 9.3. Checklist for Workstation Layout and Dimensions.

Review Topic	**Comments on quality of evidence**
1 Was the correct team chosen for developing the detailed design of control suite arrangement?	
2 Was all necessary input material gathered that relates to control suite arrangement?	
3 Was the detailed design of control suite arrangement planned appropriately?	
4 Were the detailed dimensions and layouts of each workstation documented appropriately?	
5 Were any conflicts in requirements for arrangement resolved?	
6 Have the review questions from CRIOP Part 1, section 1 (layout) been answered appropriately?	

Step 9.4: Design of Displays and Controls

Purpose

The purpose of this step is to develop appropriate design specifications for the controls and displays used in the CCR room layout.

Introduction

A good HMI design will enable the operator to fully understand and control the process. The displays present the information the operator needs to: monitor the status of the installation; to understand what is happening with the system at any given point in time; and to decide what control actions to take. Controls allow the operator to take all potentially necessary actions. Currently the major problem in relation to HMI design is that there is a lack of analysis of operators' information needs that influence HMI requirements. These needs are now determined from the results of the functional and task analyses performed in Phase B. In particular, link analysis performed in Step 4 defines the sequence and frequency in which controls and displays are used and will enable the design team, along with the relevant standards and guidelines, to define the most appropriate layout for controls and displays.

The issue of display and control design is generally well covered by existing standards and guidelines, and other than referring to these, this step is relatively brief.

Objectives

- Ensure the information displayed satisfies the operators' requirements
- Ensure controls enable the operator to adequately control the installation
- Ensure both displays and controls conform to human factors principles
- Ensure that the design specifications for displays and controls satisfy the functional specifications developed in Step 3

Regulatory Requirements

- Safety and Communication Systems Regulations §§13, 14, 16-25
- SAM Regulations § 35d
- NORSOK S-002 §§ 4.9.5 and 5.2.2
- NORSOK I-CR-004 § 5.2.3

Other Standards and Guidance

- NORSOK I-002 §§ 6.1-6.4
- ISO/DIS 11064-1 International standards Organisation (1999a)
- *Ergonomics in Process Control Rooms Part 2: Design Guideline*. International Instrument Users' Associations (1998) §§ 8 and 9

- Norwegian Petroleum Directorate. Menneske-maskin forhold i kontrollrom: Ergonomiske analyser og retningslinjer: §§ 2, 6, 7
- CRIOP. SINTEF (1990)

Information Sources

- Information from phase B and C, particularly information from the link analysis
- Current copies of regulations, external standards, and the standards that the project has set itself
- Detailed design specifications for displays and controls

Review Guidance

The two most thorough sources of guidance for this section are: International Instrument Users' Associations (1998) *Ergonomics in Process Control Rooms Part 2: Design Guideline*, particularly chapter 8 on interaction design; and NORSOK I-002 (Draft 12 of rev. 2) *Common Requirements Safety and Automation System.*

1. **Was the correct team chosen for developing the detailed design for controls and displays?**

   The correct team should consist of people with a mix of appropriate skills but should include ergonomists, human factors experts and experienced operators.

2. **Was the appropriate input material gathered as a basis for the detailed specification for controls and displays?**

   Appropriate materials are:

   - list of requirements from relevant standards and regulations,
   - list of goals and requirements from phase A
   - list of requirements from analyses in phase B
   - conceptual design specification from phase C

   Note: the Safety and Communication Systems Regulations §§13, 14, set general requirements on safety objectives and acceptance criteria for safety systems.

   Note: the Safety and Communication Systems Regulations §§ 16-25 set specific requirements on particular safety systems.

   Note: ISO/FDIS 11064–1 recommends that the design specifications satisfy the functional specifications and task requirements from Step 3.

   Note: NORSOK S-002 Rev. 3: § 4.9.5 sets requirements for the use of task analysis and § 5.2.2 sets requirements for minimising of operators mental workload.

   Note: NORSOK I-CR-004 § 5.2 sets requirements for the man-machine interface.

   Note: NORSOK I-002 § 6.1-6.4 gives very detailed guidance and suggestions for the HMI design.

3. Was the detailed design for controls and displays planned appropriately?

Appropriate planning includes:

- list the monitoring and control tasks;
- list the information requirements for those tasks;
- identify necessary control actions
- review vendor's interaction philosophy for human factors issues relating to the instrumentation system.
- study the dialogue principles in the process instrumentation system;
- establishing an HMI and alarm philosophy for the CCR; and
- develop HMI proposals.

Note: "Ergonomics in Process Control Rooms" gives detailed guidance on planning.

4. Was an appropriate method used to develop the detailed design specification for controls and displays?

An appropriate method would be to build a mock-up or models to test out the design specifications, to ensure they are appropriate, and to identify conflicts and discrepancies in the design.

5. Were the conflicts resolved?

This means that for identified discrepancies:

- resolutions have been developed and documented;
- non-conformities have been identified;
- resolutions have been implemented; and
- resolutions have been checked for potential side-effects.

6. Was the detailed design process for displays and controls documented appropriately?

There should be a record of the detailed design process, including:

- team members;
- input materials;
- schedule;
- methods used; and
- the design results, including deviations, non-conformities, assessments against criteria, resolutions and resulting changes.

7. Does the layout of displays and controls conform to ergonomic principles?

Information from the standards and guidelines can be used to review the design fully.

Note: the SAM Regulations, § 35 d sets requirements that equipment for monitoring, control, and supervision of production processes, technical devices, or work operations be

designed and arranged in accordance with recognized ergonomic principles for man-machine interaction.

Note: NORSOK S-002 4.9.5, requires that displays and controls are designed in accordance with acknowledged ergonomic principles.

Note: NORSOK I-002 § 6.1-6.4 gives very detailed guidance and suggestions on picture design, including the use of colour, symbols, logical structure, etc.

8. Has a CRIOP Phase 1: General Analysis of Control and Safety Systems been conducted?

An evaluation using this part of CRIOP will help to establish the appropriateness of the design.

Table 9.4 Checklist for Design of Displays and Controls

Review Topic	Comments on quality of evidence
1 Was the correct team chosen for developing the detailed design for controls and displays?	
2 Was the appropriate input material gathered as a basis for the detailed specification for controls and displays?	
3 Was the detailed design for controls and displays planned appropriately?	
4 Was an appropriate method used to develop the detailed design specification for controls and displays?	
5 Were the conflicts resolved?	
6 Was the detailed design process for displays and controls documented appropriately?	
7 Does the layout of displays and controls conform to ergonomic principles?	
8 Has a CRIOP Phase 1: General Analysis of Control and Safety Systems been conducted?	

Step 9.5: Design of the Work Environment

Purpose

The main objective of a design step for design of the work environment is to ensure that it satisfies relatively well-developed regulations and standards relating to the effects on people of things like temperature, humidity, vibration, noise and lighting. The intention is to provide a safe, healthy, comfortable and efficient place to work.

Introduction

The 'work environment' is defined broadly as the physical, chemical, biological, social and cultural factors surrounding a person in his or her work tasks (ISO/DIS 11064–2). The general approach is to design the work environment to meet performance, safety and comfort needs. Consequently, designers bring into a project the relevant information about environmental factors that can affect these issues. Applicable standards and sources of data for detailed design work were identified in Step 1 of the project.

Objectives

ISO/FDIS 11064–1 states that the objective of this step for the design team is to ensure that the design specifications meet ergonomic criteria. The specifications should cover:

- the thermal environment;
- air distribution and composition;
- the lighting environment;
- the noise and vibration environment; and
- aesthetic design.

All of these areas are specialist fields of expertise in themselves, in which ergonomics or human factors plays some role.

Regulatory Requirements

- SAM Regulations §§ 13, 16, 17, 32 litera h and §§ 40 - 44
- NORSOK C-001 § 6.5
- NORSOK I-CR-004 § 5.1.2 d
- NORSOK S-002 §§ 4.4, 4.8, 4.9.1–4.9.4 and 4.11

Other Standards and Guidance

- ISO/FDIS 11064–1 International Standards Organisation (1999a) Step 9E

- ISO/FDIS 11064–6 International Standards Organisation (not yet published) Appendix 10A
- Designers and reviewers should also be aware of the ISO 9241 series, which covers ergonomic requirements for office work with visual display terminals, particularly part 6 on environmental requirements.
- *Ergonomics in Process Control Rooms Part 2: Design Guideline*. International Instrument Users' Associations (1998) §7
- CIBSE Code for Interior Lighting (1994)
- CRIOP. SINTEF (1990)
- Norwegian Petroleum Directorate. Menneske-maskin forhold i kontrollrom: Ergonomiske analyser og retningslinjer: §§ 2, 6, 7

Information Sources for the Reviewer

- Current copies of regulations, standards, building codes, policies, etc., and the standards that the project has set itself in Step 1
  - Specialists in aspects of environmental design may work to particular standards, regulations and laws, such as codes for interior lighting, HVAC, noise and vibration exposure limits.
- Information from phase C, particularly information on the preliminary control suite layout and placement of operator stations
- Specifications for control suite arrangement from Step 9.1
- Specifications for control room layout from Step 9.2
- Specifications for workstation layout and dimensions from Step 9.3
- Specifications for the design of displays and controls from Step 9.4

Review Guidance

1. Was the correct team chosen for developing the detailed design of the work environment?

The correct team should consist of people with a mix of appropriate skills but should include ergonomists, human factors specialists, building surveyors, lighting experts and HVAC engineers.

2. Was all necessary input material gathered for the design of the work environment?

Appropriate materials are:

- lists of requirements from relevant standards and regulations,
- lists of goals and requirements from phase A
- lists of requirements from analyses in phase B
- conceptual design specifications from phase C

Note: the SAM Regulations § 32 litera h sets requirements for daylight in control rooms

Note: the SAM Regulations §§ 40–44 set requirements for noise, vibration, lighting and indoor climate.

Note: the SAM Regulations § 13 refers to the drawing up of work environment objectives.

Note: NORSOK C-001 § 6.5 refers to requirements regarding noise, vibration, ventilation, illumination, glare, reflections, etc.

Note: NORSOK I-CR-004 § 5.1.2 defines precise requirements for temperature, humidity, lighting, etc.

Note: NORSOK S-002 lays down specific requirements in § 4.4, 4.8, 4.9.1–4.9.4 and 4.11.

Note: ISO 9241-6 gives guidance on design of the physical work environment.

Note CIBSE (1994) covers lighting design comprehensively.

3. Was the detailed design of the work environment planned appropriately?

Appropriate planning includes:

- identification of general environmental requirements for the CCR; then
- identification of specific tasks to be performed in specific areas of the CCR and setting additional requirements for theses task areas;
- assessment of lighting needs after the final location of the workstations has been set.
- arrangements for grills and heating ducts after the final seating arrangements have been made.

Note: International Instrument Users' Associations (1998) gives guidance on planning the physical work environment.

4. Was the detailed design of the work environment documented appropriately?

There should be a record of the detailed design process, including:

- input materials;
- the team members;
- the schedule;
- methods used; and
- the design results, including deviations, non-conformities, assessments against criteria, resolutions and resulting changes.

Note: the Sam Regulations § 16 set requirements for systematic evaluations and analyses.

5. Were any conflicts resolved?

Design documentation needs to show for identified discrepancies that:

- resolutions have been developed and documented;
- non-conformities have been identified;
- resolutions have been implemented; and
- resolutions have been checked for potential side-effects.

Note: the SAM Regulations § 17 refers to checks that the work environment is satisfactory. See also Step 11, which reviews operating experience and refers to the work environment.

6. Have the review questions from CRIOP Part 1, section 2 (environment) been answered appropriately?

This section of CRIOP gives a brief review of vibration, auditory environment, ventilation, windows, lighting, colour, temperature, humidity and dust.

Table 9.5. Checklist for Work Environment Design.

Review Topic	**Comments on quality of evidence**
1 Was the correct team chosen for developing the detailed design of the work environment?	
2 Was all necessary input material gathered that relates to control suite arrangement?	
3 Was the detailed design of control suite arrangement planned appropriately?	
4 Was the detailed design of the work environment documented appropriately?	
5 Were any conflicts in requirements for arrangement resolved?	
6 Have the review questions from CRIOP Part 1, section 2 (environment) been answered appropriately?	

Step 9.6: Operational and Management System Design

Purpose

The purpose of this section is to ensure that appropriate detailed design specifications are developed for organisation and management of control room activities.

Introduction

This section addresses issues such as job design, allocation of tasks to individual operators, staffing, workload, division of responsibilities, and communication requirements. It follows on from the analysis begun in Step 5, which are deepened and become more specific as the physical design of the control centre becomes more specific. These more detailed requirements from the job and work organisation analysis must then be accounted for in the detailed design. ISO/FDIS 11064-1 gives the following guidance on what might be included for consideration in this step:

- Training organisation
- Maintenance organisation
- Shift patterns
- Training and selection regimes
- User requirements, including company policies and cultural factors, have to be appropriately reflected in the design
- Contacts with other groups outside the control room have to be considered
- Communication requirements, such as between operators in the control suite and operators in local control stations, have to meet operational requirements,
- Secondary users' requirements and characteristics have to be appropriately considered.

Objectives

- Ensure that aspects of control room work other than process control have been identified and detailed design requirements set
- Ensure that appropriate management systems have been developed to control all activities in the control centre

Regulatory Requirements

- Management Systems Regulations § 8.2 litera a - g
- SAM Regulations § 16
- Safety and Communications Systems Regulations § 40
- Emergency Preparedness Regulations § 14
- Safety Regulations § 40

- NORSOK S-002 §§ 4.5 and § 4.7

Other Standards and Guidance

- *Ergonomics in Process Control Rooms. Part 2: Design Guideline*. International Instrument Users' Associations (1998) §§ 3.3 and 4
- ISO/DIS 11064-1 International Standards Organisation (1999)
- CRIOP. SINTEF (1990)

Information Sources

- Regulatory documents regarding operations and managerial requirements
- Results of task analyses in Step 4
- Results of job and work organisation analysis in Step 5 e.g., planned division of responsibilities, staffing, training, procedure and communication requirements, etc.
- Detailed design specification for operational and managerial requirements

Review Guidance

1. **Was the correct team chosen for developing the detailed design for operational and management systems?**

   The correct team should consist of people with a mix of appropriate skills but should include human factors experts, organisational psychologists and experienced operators.

2. **Was the appropriate input material gathered as a basis for the detailed specification for operational and management systems?**

   Appropriate materials are:

   - list of requirements from relevant standards and regulations,
   - list of goals and requirements from phase A
   - list of requirements from analyses in phase B, particularly the results of Step 5
   - conceptual design specification from phase C

   Note: the Management Systems Regulations § 8.2 litera a – g set requirements for management systems.

   Note: the SAM Regulations § 16 set requirements for systematic analyses to be carried out in the case of major organisational changes.

   Note: the SAM Regulations § 35 set requirements for job satisfaction issues.

   Note: the Emergency Preparedness Regulations § 14 set requirements for communications in emergency situations.

   Note: the Safety Regulations § 40 set requirements for communications tasks.

   Note: ISO/FDIS 11064-1 § 9F states that detailed solutions for operational and management requirements should be developed and gives guidance on what this includes.

3. Was the detailed design for operational and management systems planned appropriately?

Appropriate planning includes:

- list operator tasks;
- analyse tasks requirements;
- combine tasks into jobs; and
- analyse implications of job design for local work organisation and layout of workstations.

Note: Ergonomics in Process Control Rooms gives detailed guidance on work organisation and management.

Note: NORSOK S-002 §§ 4.5 and § 4.7 sets requirements for an organisation and manning study and also a psycho-social analysis that addresses job satisfaction issues.

4. Was an appropriate method used to develop the detailed design specification for operational and management systems?

An appropriate method would be to use walk throughs and CRIOP scenario analysis to test out the design specifications, to ensure they are appropriate, and to identify conflicts and discrepancies in the design.

5. Were the conflicts resolved?

This means that for identified discrepancies:

- resolutions have been developed and documented;
- non-conformities have been identified;
- resolutions have been implemented; and
- resolutions have been checked for potential side-effects.

6. Was the detailed design process for operational and management system documented appropriately?

There should be a record of the detailed design process, including:

- team members;
- input materials;
- schedule;
- methods used; and
- the design results, including deviations, non-conformities, assessments against criteria, resolutions and resulting changes.

Note: the Safety Regulations § 40 set requirements for documentation of communications tasks of particular importance to safety.

7. Does the operational and management system design conform to human factors principles?

Information from the standards and guidelines can be used to review the design fully.

8. Has a CRIOP Phase 1: General Analysis of Job Organisation been conducted?

An evaluation using this part of CRIOP will help to establish the appropriateness of the design.

9. Have all control room operations been identified and considered in the detailed design?

Evidence should be available that all operations identified in the allocation of function and task analyses have been considered in the detailed design.

10. Are management systems that comply with the management system regulations in place for control room operations?

A list of control room operations to be managed should be drawn up. Management systems can be evaluated against government regulations and company requirements for management systems.

11. Have the training aspects identified from Step 5 been accounted for?

During the Job and Work Organisation analysis operator training needs have been identified. The type of training given and the quality of the training system can be evaluated using CRIOP Part 1, section 6: Training, and the questions in Step 9.8 of this methodology.

12. Have all procedures requirements identified from Step 5 been accounted for?

During the Job and Work Organisation analysis procedure needs have been identified. CCR procedures can be evaluated using the questions in Step 9.7 of this methodology.

13. Have maintenance and its organisation been adequately considered in the detailed design?

Maintenance management can be reviewed by referring to the "Maintenance Baseline Study" (NPD1998). Maintenance procedures can be reviewed using the questions in Step 9.8 of this methodology.

14. Have communication requirements for all situations been examined and appropriate solutions reached?

The results of analyses in Steps 4 and 5 have set requirements which should have been taken into account in the detailed design. These include communication within the control room and with other groups outside the control room in all operational situations. Special attention should be given to emergency situations.

Note: the Emergency Preparedness Regulations § 14 defines communication and sets requirements for it in emergency conditions.

Table 9.6. Checklist for Operational and Management System Design

Review Topic	**Comments on quality of evidence**
1 Was the correct team chosen for developing the detailed design for operational and management systems?	
2 Was the appropriate input material gathered as a basis for the detailed specification for operational and management systems?	
3 Was the detailed design for operational and management systems planned appropriately?	
4 Was an appropriate method used to develop the detailed design specification for operational and management systems?	
5 Were the conflicts resolved?	
6 Was the detailed design process for operational and management system documented appropriately?	
7 Does the operational and management system design conform to human factors principles?	
8 Has a CRIOP Phase 1: General Analysis of Job Organisation been conducted?	
9 Have all control room operations been identified and considered in the detailed design?	
10 Are management systems that comply with the management system regulations in place for control room operations?	
11 Have the training aspects identified from Step 5 been accounted for?	
12 Have all procedures requirements identified from Step 5 been accounted for?	
13 Have maintenance and its organisation been adequately considered in the detailed design?	

14 Have communication requirements for all situations been examined and appropriate solutions reached?	

Step 9.7: Procedures

Purpose

The purpose of this step is to ensure that appropriate procedures are developed for CCR work and that there is a system for keeping them up to date.

Introduction

For the purpose of this document, the term "procedures" means formal written procedures and any job aids, work instructions, etc., that are used in the control room.

Although control room procedures are not mentioned explicitly in government regulations, there are a number of general requirements which cover procedures development, management systems and content. For example:

- The Management Systems Regulations apply to documentation systems, including procedures.
- The SAM Regulations require that when applying the results of risk assessment, probability-reducing measures take priority over consequence reducing measures. Procedures are an important factor in reducing the probability of human error and should be included in these measures.

Procedures are intended to support the CCR operators and maintenance staff by giving step-by-step instructions on how to carry out tasks. They compliment training and are intended to reduce human error by reducing the probability of:

- omitting steps in a sequence;
- performing the steps in the wrong sequence;
- performing the right step but on the wrong piece of equipment.

There are many problems associated with procedures, most of which stem from safety culture problems. Procedures are often regarded as something that novices use when training on a job and that are no longer required when the person becomes skilled. It is not the cases that procedures are no longer required. Instead what is needed is a different type of procedure; something less detailed, for example, a checklist that aids memory. Where there is a lack of commitment to procedures, often too little resources are spent on their development and management overlook non-use and non-compliance.

Procedures should be controlled by an efficient and effective management system and should be developed in association with the training programme to ensure that they are compatible. Their development follows from the analyses carried out in Step 4: Definition of Task Requirements. A comprehensive guide to the procedure writing process can be found in US Department of Energy Standard DOE-STD-1029-92: Writer's Guide for Technical Procedures. Appendix 9.7A can be used as additional review guidance if there is uncertainty

about the quality or appropriateness of the Procedures Management System and the Procedure Writers Guide.

Objectives

- Ensure that a systematic approach to procedures development is used
- Ensure that the development process is documented
- Ensure the procedures are usable and reflect the way the task is really done
- Ensure that training and procedure systems are compatible and linked so that if an aspect in one system is changed then a corresponding update will occur in the other
- Ensure there is a system for monitoring and updating procedures in line with changes or modifications to the control room during the design process or within the life of the control room.

Regulatory Requirements

- Management Systems Regulations
- SAM Regulations §§ 19, 25 and 35
- Emergency Preparedness Regulations § 16
- Safety Regulations §§ 10, 12 and 20
- NORSOK O-DP-001:§ 7.2.1

Other Standards and Guidance

- ISO/FDIS 11064-1 International Standards Institute (1999a)
- DOE-STD-1029-92 US Department of Energy (1992)

Information Sources for the Reviewer

- Regulatory requirements for management systems
- Mission statements, company standards, policies and administrative controls relating to procedure systems
- Results of analyses, e.g., task analyses, error analyses, walk-throughs, talk-throughs, modelling, simulation, or desktop reviews, etc.
- Lists of all technical information such as specifications, engineering drawings, etc., used in the development of the procedure
- Contents of the procedure's tracking file
- Examples of different types of procedures
- Procedure development guidance
- Information on the procedures storage and retrieval system

Review Guidance

1. Is a list of all CCR tasks available that covers all operational modes?

A list of tasks should be available as a result of Steps 2, 3 and 4.

Note: NORSOK O-DP-001 § 7.2.1 gives a list of applicable operational modes and requires that operating, start-up and commissioning instructions are developed in parallel with system design to ensure these operational requirements are optimised.

2. Was a systematic method used to decide which of these tasks need procedures to support the operator?

Systematic means there is a basis for selecting the tasks that considers:

- safety criticality;
- consequences if the task is done wrongly.
- task performance problems found from the OER;
- frequency that individual operators carry out the task;
- training and experience of the operators.

3. Was consideration given to ensure the type of procedures developed were appropriate for the situation?

Each type of situation should have an appropriate type of procedure. In normal conditions and at start up and shut down, it is better to have task-based procedures where the operator selects a procedure specific to the task to be carried out. Emergency situations are best supported by symptom-based procedures, which enable the operator to apply the correct remedial actions.

4. Was appropriate information and expertise used in developing the CCR procedures?

Appropriate information and expertise includes:

- a formal task analysis (refer to Step 2);
- consultation with present operators where modifications and upgrades are carried out or potential end-users and operators with similar experiences in the case of new control rooms;
- consultation with technical and engineering personnel;
- consultation with safety personnel.

☝ User input has many advantages including ensuring that the procedures are realistic and reflect how the task is done in practice, and by creating a feeling of ownership which will increase the likelihood of the procedures being used and followed.

Note: the SAM Regulations § 25 set requirements for employee participation in important areas of their work."

Note: ISO 11064-1 advises that procedures should be based on task analysis.

5. Is a list of documentation that was used to develop the procedures available?

Appropriate documentation includes:

- regulatory requirements;
- company standards and policies;
- operational safety requirements
- relevant action plans in the emergency preparedness plan;
- technical specifications;
- vendor information;
- engineering drawings; and
- operational feedback from:
    - incident investigation
    - alarm handling problems
    - maintenance problems
    - result of practice exercises.

6. Was appropriate user information included in developing the basic content of the procedures?

Appropriate user information includes:

- user feedback on existing procedures;
- interviews and suggestions for improvement from operators familiar with similar activities;
- frequency of task performance by individual operators;
- level of training of the user.

End users and those currently involved in similar tasks have first hand knowledge of problems with existing procedures and are most qualified to say how the job is done in practice. Information is needed about task frequency and level of operator training to ensure the procedure is the correct type and of an appropriate level. This should be documented for future use.

Note: the SAM Regulations § 35 require that the individual employee's evaluations and experience related to own work situation should be included as the basis for the planning and arrangement of the work.

7. Does each procedure have a tracking system?

There should be a system for assembling all the data used in developing the procedure and that tracks revisions of the procedure. This enables the writers and the reviewers to have quick and easy access to the relevant information. If a procedure is being revised and there is no documentation for the existing procedure, then it cannot be relied upon and its accuracy should be verified. The documentation should be revised during procedure preparation and revision to ensure the final version contains accurate and relevant information. Examples of information to be found in such a file are:

- results of the task analysis;
- documentation that was used in developing the procedure;
- user information used in developing the procedures;
- information used for tracking revisions.

8. Have procedures been developed in different formats?

Different formats can be used depending on:

- the nature of the task;
- it's complexity;
- the demand the task makes on the operators memory;
- how often it is done;
- the type of user;
- user knowledge and experience.

Procedures should have a level of detail that is consistent with qualifications and experience for the user. Different tasks and different levels of expertise may require different formats in procedures. One format to suit all users can result in procedures that are difficult to use. This is likely to result in failure to use procedures. Different formats are:

- Flowcharts,
- Checklists,
- step by step,

An experienced operator may not need a detailed set of action steps for a particular task so a checklist may be sufficient. For the same task, a trainee will need the benefit of a fully documented procedure. Different users that may be included are:

- operators,
- trainees,
- trainers,
- maintenance staff.

☝ It should be remembered that when operators are working under stress, i.e., in emergency situations, then memory capacity decreases. Therefore emergency operating procedures should be detailed enough to minimise reliance on memory.

9. Do the procedures conform to the standards for format and writing style that are laid down in the Operating Company's writer's guide?

Incorporating accepted human factors principles about format and writing style into procedures increases the likelihood that the procedures will be easier to use and follow. Usability should be determined by evaluating the degree to which procedures follow the guidance outlined in the writer's guide. If no writer's guide is available, or if the quality of the guide is questionable, then procedures can be evaluated against the checklist in Appendix 9.7A.

10. Do the procedures routinely give information about why the task should be done in the way described?

Operators' understanding is improved and the likelihood of compliance increased if they are given clear information on why a task should be performed in certain way. They should have a clear understanding of the risks associated with particular procedures.

11. Has an appropriate method been used to identify and assess consequences of errors that can be made when carrying out the procedure, and as a result warnings, cautions, error prevention and error recovery strategies have been included at these points?

In certain operating conditions, certain procedure steps can be more prone to error than others. These should be identified and the user informed about what type of errors can occur, what potentially hazardous system states these errors can result in, and how to recover from these errors and return the system to a safe state. A checklist for evaluating warnings cautions and note is available in Appendix 9.7A.

Appropriate methods of assessment include:

- assessment by technical and safety personnel;
- HAZOPs;
- Human Error Analysis;
- Critical Operations Analysis.

Note: the Emergency Preparedness Regulations § 16 require that measures that prevent a hazardous situation developing into an accident situation shall be given priority over measures that reduce the consequences of an accident situation.

12. Have inspections or controls been included at appropriate points to verify the task is being performed correctly?

Examples are:

- self-checks and sign offs;
- second checks and sign offs.

Self-verification is useful as an aid memoir but is not effective if a step is safety critical. In that case, it should be verified by a second person.

Procedures require verification and validation. Ideally, independent reviewers, i.e., not those responsible for development, should perform the verification and validation.

13. Have procedures been verified to ensure that their technical content is accurate?

This includes:

- simulated walk-throughs in the field;
- consultation with user representatives;
- consultation with technical and engineering personnel;
- consultation with safety personnel;
- periods of probation or trial use.

A walk-through or simulation should be ensured that:

- the description of equipment and equipment numbers given in the procedure matches the actual equipment;
- the units used in the display and their ranges, set points, etc., match those in the procedure
- the work can be performed in the sequence specified.

14. Did the walk-through ensure that intended task could be carried out without the need for additional information?

This means that the user could perform all the necessary tasks without obtaining additional information or direct assistance from persons not specified in the procedure.

15. Have steps been taken to ensure that the requirements of procedures are compatible and do not conflict with other safety requirements or other procedures?

This means that safety personnel have been consulted regarding possible conflicts to ensure users will not be faced with decisions about which set of instructions to apply.

16. Are procedures easily accessible for CCR operators?

This means:

- there is a clear system for filing different types of procedures;
- they are available close to their point of use;
- emergency procedures can be quickly and easily distinguished from other types of procedures;
- there are enough copies for everyone who needs them;
- support documentation is referenced and available in the system;
- EOP's should be located at the relevant work points.

17. Are procedures routinely checked against operating practice to ensure compliance?

Direct methods include:

- supervisory checks;
- verification by countersigning;
- checklists;

Indirect methods include:

- incident reports;
- unsafe act monitoring;
- non-compliance reports;
- near-miss reports;
- quality audits;
- procedure audits;
- task simulations;
- operator feedback.

Reasons for non-use should be identified and considered as part of the OER to be used in future procedures development. The checklist above provides suggestions for methods that can be used. Operator feedback should especially be encouraged.

18. Is there a systematic method for ensuring that when procedures are developed or revised then the relevant operator training will be updated?

The procedures and training systems should be well integrated at both initial and refresher training levels. New procedures and those undergoing revisions should be actively integrated into the training programme and a system should exist for this to happen in an effective way.

19. Are operators trained in the actual use of a procedure?

Operators should be required to demonstrate competence in specific written procedures.

Table 9.7. Checklist for Procedures

Review Topic	Comments on quality of evidence
1 Is a list of all CCR tasks available that covers all operational modes?	
2 Was a systematic method used to decide which of these tasks need procedures to support the operator?	
3 Was consideration given to ensure the type of procedures developed were appropriate for the situation?	
4 Was appropriate information and expertise used in developing the CCR procedures?	
5 Is a list of documentation that was used to develop the procedures available?	
6 Was appropriate user information included in developing the basic content of the procedures?	
7 Does the procedure have a tracking system?	
8 Have procedures been developed in different formats?	
9 Do the procedures conform to the standards for format and writing style that are laid down in the Operating Company's writer's guide?	
10 Do the procedures routinely give information about why the task should be done in the way describe?	
11 Has an appropriate method been used to identify and assess consequences of error made carrying out the procedure, and as a result warnings, cautions, error prevention and error recovery strategies have been included at these points?	
12 Have inspections or controls been included at appropriate points to verify the task is being performed correctly?	
13 Have procedures been verified to ensure that their technical content is accurate?	

14 Did the walk-through ensure that intended task could be carried out without the need for additional information?	

15 Have steps been taken to ensure that the requirements of procedures are compatible and do not conflict with other safety requirements or other procedures?	
16 Are procedures easily accessible for CCR operators?	
17 Are procedures routinely checked against operating practice to ensure compliance?	
18 Is there a systematic method for ensuring that when procedures are developed or revised then the relevant training will be updated?	
19 Are operators trained in the actual use of a procedure?	

Appendix 9.7A: Procedure Usability

Incorporating accepted human factors principles about format and writing style into procedures increases the likelihood that the procedures will be easier to use and follow.

When a writer's guide is not available or if the writer's guide is in question, procedure usability can be determined by evaluating the elements of writing style and format and organisation. The list that follows each element describes characteristics that increase the likelihood that a procedure will be performed successfully.

Writing Style

The information in a procedure is presented in a manner that increases the likelihood that the task will be performed successfully.

Procedure users can be working under difficult and sometimes stressful conditions and therefore procedures should be written in a way that enables the user to understand the intended meaning quickly and easily. Procedures are more likely to be performed successfully if:

1. The level of detail is appropriate for the complexity of the task and the expected ability of the users.

2. References to equipment or documents contain complete identification information, including plant unit applicability, and exactly match equipment labels.

3. Writing style is consistent among procedures within the company and within the same procedure type.

4. Language is simple, concise and everyday.

5. Short, simple sentences are used.

6. Word definitions are consistent.

7. Quantities are specified where possible, for example, " drain tank at a rate of X litres/ second" is used instead of "drain tank slowly."

8. Acronyms and other abbreviations are used consistently and are defined explicitly.

9. Double negatives and terms like "unless" and "except" are avoided.

10. Footnotes are avoided in the main body of the procedure as they break up the line of thought.

11. References are in brackets at the end of a sentence.

12. Quantitative words are used in instructions, i.e., numbers are spelt out.

13. Numerical units used in procedures correspond to the units on the related instrumentation.

14. Diagrams are used instead of long and detailed descriptions.

15. Descriptions of actions to be taken are easy to understand and unambiguous.

16. Multiple actions are written in order of sequence and clearly identify when actions must be completed in order of occurrence.

17. Procedures are written so that sequences of actions are consistently broken down into action steps. Actions steps are short and concise sentences that have one action (verb) per step where possible. Reading and understanding is quicker if instructions are presented in this way. Action steps are written as separate and positive commands, i.e.,
    - One action verb and one object are used where possible.
    - Each action step is short and concise.
    - They are written in the active voice.

18. Conditional statements are presented using the appropriate format, that is,
    - - IF and WHEN are used to present a condition.
    - - THEN is used to present an action.
    - - IF NOT is used in combination with THEN to present an alternative.
    - - NOT is used to emphasise an opposite condition (NOT running).
    - - AND is used to present all conditions that must be met before taking action.
    - - OR is used to present one or more conditions that must be met before taking action.

Format and Organisation

An uncluttered appearance and clear structure of the information in a procedure increase the likelihood that the task will be performed successfully.

Procedures are more likely to be performed successfully if:

1. Procedure identification information is adequate to ensure the procedure is complete and current.

   This means that the pages are clearly marked with the following information:
   - procedure number;
   - platform or equipment number;
   - revision number and date;
   - page number.

   and that the first pages are also marked with:
   - a descriptive title that identifies the system, equipment, process or activity described in the procedure;
   - approval date and signature from operators, technical staff and management representatives

- review date.

This information should be checked when the procedures are placed in the storage system in the CCR to ensure that the document is complete and that no errors have been made during reproduction.

2. The introductory section gives appropriate information for the users:

   This includes the following where appropriate:

   - Table of contents;
   - the conditions for use;
   - precautions and limitations;
   - information on planning and co-ordination;
   - lists of actions that must be performed before use, e.g., obtaining work permits, approval and notifications;
   - lists of other documents, drawings etc, needed to perform the task;
   - list of special tools, equipment, parts and supplies.

3. Organisation is hierarchical, logical, and consistent, and reveals the organisation to users through the use of headings.

4. Title, headings, font and legibility enable the correct information to be found quickly and easily.

5. Step numbering and structure is not overly complex.

6. Checklist information reflects the sequence of information in the steps of the procedure.

7. Aids are used to help users to track their progress through a procedure where appropriate.

8. Minimum type size should be 12 point and a serif typeface and should use proper punctuation;

9. The procedure is legible in the worst expected conditions for use, i.e., type is readable:

   - at an expected distance within which the procedure is used,
   - after copying, and
   - under degraded lighting.

10. Highlighting should be used to draw attention to important information.

11. Figures and charts are explicitly and uniquely identified so they are easy to find within the procedure.

12. Warnings, cautions and notes (WCNs) are consistent.

    - WCNs are obvious and address a single topic.
    - WCNs come before the related action step.

- WCNs contain no actions.
- WCs identify the consequence of wrong action.
- Ns supply only supplemental information.

13. The procedure clearly indicates the final step.

14. Appendices and attachments provide explicit guidance for their allowed use and present relevant information that would be difficult to integrate into the procedure.

15. Appropriate margin size (minimum 1.27cm) ensures that information is not lost during copying. Incorrect punctuation can change the meaning of an instruction.

Procedures Management Systems

The following questions can be asked in addition to the previous review guidance if there is uncertainty about the quality or appropriateness of the Procedures Management System.

1. **Is there a system for dealing with regulatory requirements and changes to these requirements that affect the procedures management system?**

2. **Are responsibilities assigned to individuals regarding the functioning of the procedure management system and competency requirements set for those individuals?**

3. **Does a writer's guide exist on how written procedures should be developed?**

   This should include:

   - advice on what types of documentation should be collected;
   - advice on the various stages involved in developing procedures and what is required at each stage;
   - practical techniques and guidelines for use at each stage of the development process;
   - advice on formatting and style;
   - comprehensive advice on presentation of information; and
   - training

4. **Were the procedure developers given training in the use of the writer's guide?**

   Training should relate directly to the formal method for procedures development used by the company.

5. **Were the procedures formally verified to check for accuracy, completeness, redundancy or conflict?**

   Individual procedures should be reviewed formally and regularly (i.e., 2 year intervals at maximum). They should be also updated after information from incidents and near-misses, operator feedback, and following the introduction of new equipment and technology.

6. Are reasons for not following procedures investigated and identified?

Reasons should be identified and the causes remedied. This approach is of more value than disciplinary measures.

Step 9.8: Training

Purpose

The purpose of this step is to ensure that operators training needs are systematically identified and that appropriate training is developed.

Introduction

Currently, because the analysis of control centre tasks is generally poor, there is a lack of understanding of the skills and knowledge the operators need to operate the installation safely and efficiently. In addition to knowledge and skills, operators must have an accurate mental picture or model of how the installation functions. And, if operators are to communicate effectively both within the control room and with those outside, they must share the same model. It is important, therefore, to train the operators not only in the skills they need, but also to develop a shared model of the installation. To do this a systematic approach to training is needed. A systematic approach contains five parts:

- Control centre tasks are systematically analysed to identify the knowledge and skills needed to perform them.
- From the results of the task analysis, learning objectives are developed that include conditions and standards for performance.
- A specific, job-related, training programme is developed.
- The operator's performance is evaluated throughout the programme.
- The programme is evaluated to identify updates and revisions needed.

Once a training need is identified, the necessary training is developed, implemented and evaluated in a consistent and systematic manner. Evaluations ensure that the training is effective and feedback ensures that improvements are made to training programmes when problems are identified. Therefore, a systematic approach ensures that the skills and knowledge required by the operators, to carry out their tasks in all operating conditions evolves along with the control room and are updated when any upgrades or modifications take place.

The review guidance in questions 1 to 8 is directed at the development of training while in 9 to 14 feedback from operational experience is addressed. It is assumed that the company will have an effective and systematic training system in place. Where this is in doubt, then the appropriateness of the training system can be evaluated using the review questions in Appendix 9.8A.

In addition, it will be necessary to include training personnel in the review team at this stage, if they are not already present.

Objectives:

- Ensure that the analysis of knowledge and skills for each CCR task is adequate
- Ensure that the need for operator training is identified
- Ensure that tasks for refresher training are identified
- Ensure that there is a method for keeping training up to date when job requirements change, e.g., when control rooms are modified or replaced
- Ensure that information is collected from operators, supervisors and operational experience and used to identify potential improvements to operator training
- Ensure that external factors or internal changes are evaluated to identify their impact on job performance requirements and training needs

Regulatory Requirements.

- The Safety Regulations § 13

Other Standards and Guidance

- NUREG 1220, U.S. Nuclear Regulatory Commission (1993)
- Preparing Instructional Objectives. Mager, R.F. (1984)
- Training: Research and Practice. Patrick, J (1992)
- CRIOP. SINTEF (1990)

Information Sources for the Reviewer

- Documentation from Step 2
- Procedures or instructions that are related to changing learning objectives when requirements for job performance change
- Documentation relating to control room upgrades, modifications or changes to procedures that should make it necessary to revise or change the training
- Procedures or instructions that show how operators are selected for training or for exemptions from training
- Results of evaluations of personnel performance problems for the last two years. This should be available from the OER in Step1

Review guidance

1. **Has training been evaluated using a CRIOP Part 1: General Analysis of Training?**

2. **Was a systematic method used and documented that identified all control centre tasks across all operating conditions?**

   Operators and training personnel should have made a list of tasks specific to the control centre in Step 4. If this is not the case then task analyses should be carried out as described in Step 4

3. Was a systematic method used to decide in which of these tasks operators needed training?

Systematic means there is a basis for selecting the tasks that considers:

- whether the task is safety critical;
- percentage of operators who do the task;
- percentage of time doing the task;
- consequences of poor performance;
- frequency of doing the task;
- difficulty to learn or perform the task;
- time between starting job and actual doing the task;
- entry level skills and knowledge, e.g., tasks done on previous jobs;
- task performance problems found from operating experience.

Note: the SAM Regulations § 24 sets requirements for a systematic approach to training.

Note: the Safety Regulations § 13 requires the setting of criteria and qualification requirements for jobs that are of significance to safety.

4. Were tasks for initial training and those for refresher training identified separately?

Criteria for selecting tasks for refresher training should also compare how often tasks are actually performed by individuals, with how often they need to be performed to maintain the skills.

5. Was the analysis of the chosen tasks adequate to develop learning objectives and were the results presented in a consistent format?

Each task chosen for training should be analysed so that the following information is available in a specific and measurable form:

- ***conditions***, i.e., an event that indicates when a task is performed (e.g., when the tank high pressure alarm is activated) or that influences the performance of the task (e.g., given that temperature and pressure are normal);
- ***actions***, i.e., the behaviour required to complete the task;
- ***standards***, i.e., the specific and measurable criteria or standards that separate acceptable from unacceptable performance;
- ***skills and knowledge*** needed to do the task successfully.

6. Is there a method for keeping the task analysis up to date when job requirements change, e.g., when control rooms are modified or replaced?

This means that there are procedures that are always used and that require that all changes in operator tasks are reviewed to identify new job performance requirements. This means:

- an analysis of the impact of changes;
- revision of the training programme;
- a task analysis for new tasks or tasks that have changed significantly;

- instructions to ensure consistent results of analyses.

Note: the SAM Regulations § 24 sets requirements for training to be adapted to any altered or new risk situation.

7. Is there refresher training for difficult, critical, or infrequently performed tasks?

- Tasks should be selected for refresher training when they have the potential for degraded performance.
- The retraining lesson plan should include both classroom and performance requirements that will demonstrate an ability to perform the task.

Note: the SAM Regulations § 24 sets requirements for training to be repeated as required.

8. Were exemptions from training and task performance based on objective criteria?

- The operator to be exempted has been given a test based on requirements for job performance.
- The operator has presented documentation or certification from previous training or job experience that ensures the knowledge and skills required for job performance.

9. Is feedback formally collected from operators and used to identify potential improvements to operator training?

Operators should be asked to give feedback about how effective the training was and how it might be improved when they complete major parts of the training. The information asked for should at least include:

- adequacy of training in providing background knowledge;
- adequacy of training in developing skills;
- degree to which the training was related to job requirements;
- degree to which the training prepared the operators to fulfil job requirements.

10. Are operators asked for feedback about jobs/tasks that they did not feel adequately trained to perform and is it used to identify potential improvements to operator training?

Three to six months after completing training, operators and recent operators should be asked for feedback about the strengths of the training. The information asked for should at least include:

- unexpected difficulties found in performing tasks on the job;
- tasks that were very easy or very difficult to perform;
- additional training needed to do the job;
- types of errors made on the job;
- differences between the way tasks are done on the job and the way they are taught in training.

11. Is information collected from supervisors about the performance of operators to identify tasks that they were not adequately trained to perform and is it used to identify potential improvements to operator training?

Supervisors should be asked to give feedback or information that includes at least the following:

- tasks for which operators were not adequately trained;
- types of errors made by operators;
- suggestions for improvements in initial and continuing training;
- changes that are expected in job assignments, procedures, or equipment.

12. Is information or feedback collected from operators and supervisors about task performance that declines over time and is it used to identify potential improvements to operator training?

Performance of both simple and difficult tasks may decline over time. This is especially important for tasks that are not performed frequently but are very critical.

13. Are external factors and changes evaluated to identify their impact on CCR jobs and related training programmes?

This means:

- events on other installations should be evaluated to identify their impact on job performance and, in turn, training programmes for related jobs;
- installation of new equipment should be evaluated to identify its impact on job performance and, in turn, training programmes for related jobs;
- modifications to existing equipment should be evaluated to identify its impact on job performance and, in turn, training.

14. Will changes in requirements for job performance result in changes in training and training materials?

Changes must be made consistently in all affected parts of the training programme. As applicable, the following parts of training should be evaluated to ensure changes are consistent throughout the programme.

- classroom training;
- simulator training;
- on-the job training;
- workshop training.

There should be a method or procedure that ensures that the changes are made to ***all*** training materials that are affected by changes in requirements for job performance.

Table 9.8. Checklist for Training

Review Topic	Comments on quality of evidence
1 Has training been evaluated using a CRIOP Part 1 General Analysis of training?	
2 Was a systematic method used and documented that identified all control centre tasks across all operating conditions?	
3 Was a systematic method used to decide in which of these tasks operators needed training?	
4 Are tasks for initial training and those for refresher training identified separately?	
5 Is the analysis of the chosen tasks adequate to develop learning objectives and are the results presented in a consistent format?	
6 Is there a method for keeping the task analysis up to date when job requirements change, e.g., when control rooms are modified or replaced?	
7 Is there refresher training for difficult, critical, or infrequently performed tasks?	
8 Are exemptions from training and task performance based on objective criteria?	
9 Is feedback formally collected from operators and used to identify potential improvements to operator training?	
10 Are operators asked for feedback about jobs/tasks that they did not feel adequately trained to perform and is it used to identify potential improvements to operator training?	
11 Is information collected from supervisors about the performance of operators to identify tasks that they were not adequately trained to perform and is it used to identify potential improvements to operator training?	
12 Is information or feedback collected from operators and supervisors about task performance that declines over time and is it used to identify potential	

improvements to operator training?	

13 Are external factors and changes evaluated to identify their impact on CCR jobs and related training programmes?	
14 Do changes in requirements for job performance result in changes in training and training materials?	

Appendix 9.8A: Review Guidance for Training Systems

15. Are there learning objectives for each of the tasks being evaluated?

A learning objective:

- describes precisely what must be learned or what the operator must be able to do;
- should give the training developer the information needed to organise the objectives, and choose an appropriate setting for instruction (e.g., simulator, laboratory, workshop).

16. Do the learning objectives have actions, conditions, and measurable standards for job performance that reflect what is actually needed to do the job?

Examples are:

- *a condition*: *Given the parts of a pump, proper tools, and the approved procedure*, reassemble the pump according to the steps of the procedure.
- *an action*: Given the parts of a pump, proper tools, and the approved procedure, *reassemble* the pump according to the steps of the procedure.
- *a standard*: Given the parts of a pump, proper tools, and the approved procedure, reassemble the pump *according to the steps of the procedure.*

17. Are there procedures or instructions that ensure learning objectives are updated when requirements for job performance change?

This can be checked by:

- Reviewing documentation with respect to a recent modification or a procedure change that should have made it necessary to revise or change the training.
- Reviewing the training for the tasks related to that change to determine if the procedures or instructions were followed and recorded.

18. Are lesson plans written and formatted so that training is consistent between courses?

This means the lesson plan is a structured outline and includes:

- learning objectives;
- adequate amount and detail of content to ensure consistency;
- required support materials, e.g., equipment, tools, audio-visual aids;
- Is their enough detail in the content of the lessons to make learning objectives attainable?

19. Are the lesson plans consistent with the learning objectives?

The learning objectives and the content of the lessons should match; for example, learning objectives that require the operator to distinguish between two situations must have a lesson content that stresses the differences.

20. Is the information, both within a lesson and between several lessons, presented in a logical and appropriate sequence for learning? This means:

When several topics depend on each other, the most basic should be presented first, e.g., normal operation of a system must be covered before the operator can understand abnormal operation.

21. Is training adequately presented? This means:

The instructor should have adequate knowledge to present the content of the lesson accurately, i.e., the instructor has been trained at least to the level of knowledge to be presented in the training.

22. Do training personnel show acceptable performance in the methods and techniques for successful presentation of training in the specific settings being used, e.g., classroom, on-the-job, simulator?

The instructor should have been trained sufficiently to show:

- complete understanding of training content;
- questioning skills;
- presentation skills that include the use of appropriate equipment for the setting.

23. Are the test items or questions related to job performance requirements and learning objectives?

Test items should be consistent with what is required by the learning objectives. For example, if the learning objectives require the operator "identify," then test question or item should not ask the operator to "interpret," i.e., the test question is not consistent with the objectives even if the quality of both are good.

24. Is operators' performance evaluated regularly?

- There should be regular and frequent feedback to operators about their performance.
- The feedback should be immediate and continuous and can include self-checks that are rated or scored by the operator, such as in self-study workbooks, or by tests that are given and scored by the instructor.
- In the case of tests given by the instructor, the feedback should be prompt.

25. Is there remedial training according to established criteria when operators show weakness in specific areas or fail tests completely?

- The amount and type of remedial training should be based on the initial performance of the operator.
- The remedial training may be an independent review by the operator with the guidance of the instructor or it may be a formal retraining session.
- The remedial training should include all areas where performance was weak or inadequate.

26. Do evaluations of task performance actually test the operators' ability to do the task?

- The evaluation should require that the operator actually perform a task.
- Simulation, i.e., going through the actions without carrying them out, should only be used if actual performance might compromise equipment or platform safety. The standards for task performance are the same as requirements for job performance.
- A task can be performed on the simulator. This is considered actual performance rather than simulation.

Step 10: Verification and Validation of Detailed Design

Purpose

Step10 is a series of checks to ensure that the detailed design specification meets regulations and design standards, and will provide an acceptable control room or modification. Verification ensures that the design meets international and industry requirements and the standards that the project sets itself. Validation, on the other hand, ensures that the design conforms to users' needs and thereby that the design works.

Introduction

Verifications include checks against regulations and standards to ensure that the design meets all of the necessary regulatory requirements. Validations are performed using techniques such as CRIOP and full-scale tests and simulations. Both of these checks (verification and validation) are necessary to ensure that the design offers an acceptable solution. To be most effective, V&V should be performed at several stages in the design process, not just at the end (see Figure 10.1). There must be an opportunity to use the findings from the V&V to modify the design. That is why V&V is also advised in Step 6, and V&V-like, checking activities appear in other steps, such as Step 8. In phase D, the V&V process is applied to the detailed design that was developed in Step 9.

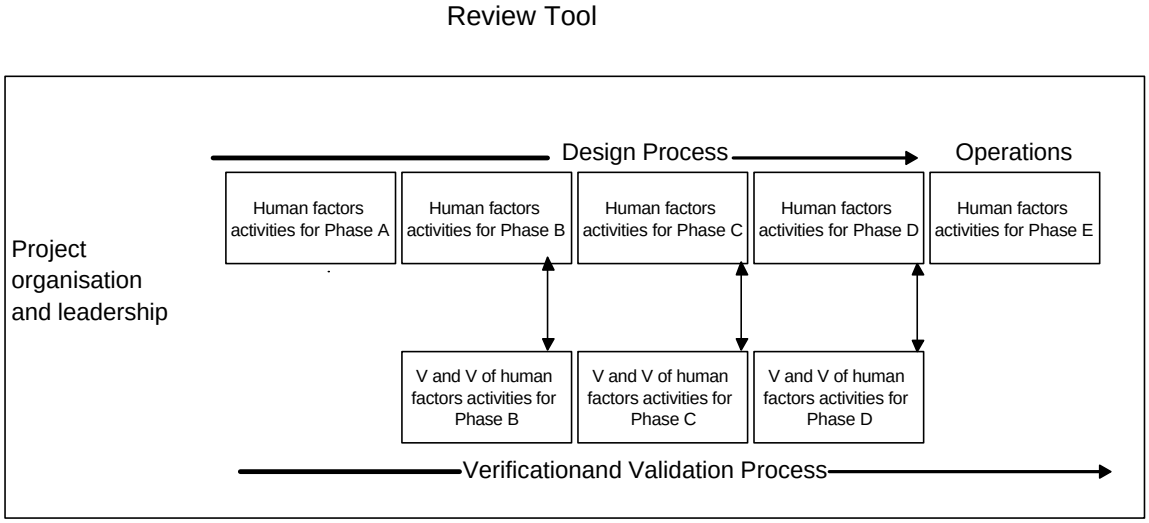

Figure 10.1. Verification and Validation Throughout a Project

Objectives

The objectives of V&V are:

- *Verification* — to check the detailed design specifications against the standards that the project set itself — whether the design is in line with requirements and constraints
- *Validation* — to show as far as possible before build and installation that the design will work as intended.

Regulatory Requirements

- NORSOK S-002 § 4.1
- Safety Regulations § 19
- SAM Regulations § 35

Other Standards and Guidance

- ISO/FDIS 11064-1 International Standards Institute (1999a)
- IEC 964 International Electrotechnical Commission (1989) § 5

Information Sources for the Reviewer

- Documentation describing the operating company's verification and validation of phase D
- Results of earlier V&V stages, such as Step 6, and work related to V&V, such as Step 8.

Review Guidance

An integrated verification and validation must be done once the detailed design specification is available. This checks that the elements of the design function together, that the design works as a whole. It is a critical step: throughout the entire process, V&V has been performed on limited system issues or at early stages of design. This step provides the only verification and validation of the control room design or upgrade as a whole. A full tabletop CRIOP analysis partly meets this requirement (Ingstad and Bodsberg,1990).

A full-scale CRIOP should be performed in a simulator, or in the control centre for maximum realism. If possible, scenarios should be run on a simulator. The CRIOP method consists of two parts:

- *General Analysis (Part 1)* — a static analysis using checklists to cover different design issues to identify weak points and non-conformances with standards and regulations.
- *Scenario Analysis (Part 2)* — a dynamic analysis to identify weak points in the control centre's ability to handle abnormal situations.

CRIOP gives a procedure for evaluating a control centre concept, in order to identify weak points in the handling of abnormal situations.

1. Has a CRIOP general analysis been carried out?

The CRIOP *general* analysis is scenario-independent. It contains a series of checklists for evaluating general design factors in the control room. These checklists are a kind of verification. However, the scope of the verification is not as great as ISO/FDIS 11064. For instance, CRIOP evaluates 'layout' as one topic, whereas the current guidelines, based on ISO 11064, contain design steps for control suite arrangement (Step 9.1) control room layout (Step 9.2) and workstation layout and dimensions (Step 9.3). In addition, some of the standards used in CRIOP may differ from the ones used for the project in question. Thirdly, many control room design standards (or at least drafts) have been written since CRIOP was published. Therefore, the CRIOP general analysis should be carried out on (and extended to) *all* of the detailed design steps individually, and the relevant design standards should be substituted in.

Note: the SAM Regulations § 35 requires that the design is satisfactory regarding workplace layout, workload, arrangement, etc.

Note: the Safety Regulations § 19 refers to verification of specific requirements for safety.

Note: NORSOK S-002 refers to general requirements for verification of the work environment for new installations and for modifications.

2. Has a CRIOP scenario analysis been carried out?

A CRIOP scenario analysis is a kind of validation of the design for abnormal situations. Based on the weak points identified, it is possible to recommend ways to improve the control centre's ability to handle abnormal scenarios.

The scenario analysis should look for potential problems and weaknesses in all areas of detailed design contained in phase D. The analysis can apply the structure given in the CRIOP section on scenario analysis, but this should be adapted to the full range of detailed design topics in phase D.

3. Have the results of V&V (CRIOP or similar) resulted in resolutions for detailed design changes?

The CRIOP method recommends that the general analysis should be documented, including suggestions for remedial measures based upon the identified weak points. ISO/FDIS 11064–1 also states that the output of Step 10 is an approved detailed design specification that both meets the project's design standards and is suitable for its intended use. Some examples of problems and resolutions for each step of phase D are shown in Table 10.1.

Table10.1. Examples of V&V of Detailed Design

Design Step	Check	Problem	Resolution
9.1: Control Suite Arrangement	Verification	Work zones did not allow communication as intended between CCR operators	Rearrange work zones consistent with communication within the noise background; reallocate workstations to different rooms in the control suite

Design Step	Check	Problem	Resolution
	Validation	Function for issuing work permits was not sufficiently considered in the control suite arrangement	Set aside space for dealing with work permits that does not interfere with other task zones
9.2: Control Room Layout	Verification	Requirement was not met that all alarms should be visible without leaving the workplace	Computerise alarms and integrate with other displays in CCR; relocate cabinets or panels
	Validation	Need was not sufficiently understood for printouts in the CCR	Provide operators with printers that can be used without leaving their task areas; relocate printers
9.3: Workstation Layout and Dimensions	Verification	Workstation VDUs were not placed correctly to meet the project's visibility and readability requirements	Redesign computer displays; redesign desk layout; use larger monitors
	Validation	Quantity of paperwork (secondary tasks) while monitoring was not understood	Computerise reporting and logging; allocate more space for manuals and procedures; introduce local library points
9.4: Design of Displays and Controls	Verification	Large screen displays were not visible from all specified locations in the CCR	Use a technology with a wider viewing angle; redesign displays; remove obstructions to sightlines; relocate displays; give slave-displays elsewhere in the control suite
	Validation	Supervisor had difficulty maintaining a mental overview	Provide overview displays in the supervisor's office; allow supervisor to hear CCR operator's conversations
9.5: Design of the Work Environment	Verification	Requirement to avoid veiling reflections on VDUs was not met	Repositions VDUs; reposition task zones; redesign lighting; add diffusers or blinds

Design Step	Check	Problem	Resolution
	Validation	Noise contribution from conversation, computer fans, printers and ventilation was larger than expected	Introduce local sound-barriers; change printers; change work organisation
9.6: Operational and Management System Design	Verification	Requirement that CCR operators could always communicate with field operators was not met	Introduce extra communications devices; reorganise control of field operators locally
	Validation	Need for periodic reports from CCR to management was not considered adequately	Introduce computerised summary reports; redesign supervisor's job; give management access to summary displays
Step 9.7: Training	Verification	A new operator was not able to carry out a procedure as required	Rewrite procedure; improve training; reallocate task; automate task
	Validation	CCR operator was required to understand and operate a new system not covered by training	Redesign new system to be similar to its predecessor; introduce a new training module; reallocate responsibility
Step 9.8: Procedures	Verification	Requirement to keep procedures up-to-date was not met	Improve procedures for updating; revise management of procedures
	Validation	Procedure was not realistic or did not match installed equipment	Improve procedures for updating; revise management of procedures

Table 10.2. Checklist for V&V Review

Review Topic	**Comments on quality of evidence**
1 Has a CRIOP general analysis been carried out?	
2 Has a CRIOP scenario analysis been carried out?	

Appendix 10A. Verification and Validation for Individual Design Steps

This section relates to phase D of the design process. The following subsections describe the verification and validation process for each of the eight design issues.

Control Suite Arrangement

Verification

- Input material: regulatory documents regarding Control suite arrangement (e.g., ISO 11064)
- Team: personnel with control centre experience, auxiliary personnel who occasionally work in the control centre (e.g., ECC)
- Method / process: comparison of the design specifications against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: design documentation, mock-up or VR model
- Team: personnel with control centre experience
- Method / process: The Control Suite Arrangement section of this methodology. Note: CRIOP Part 1 (Layout section) is not recommended here, as it is limited (i.e., it only covers the supervisor's station, the ECC, and the social corner).

Control Room Layout

Verification

- Input material: regulatory documents regarding Control Room Layout (ISO 11064)
- Team: personnel with control centre experience, auxiliary personnel who occasionally work in the control centre (e.g., ECC), ergonomist
- Method / process: comparison of the design specifications against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: design documentation, mock-up or VR model
- Team: personnel with control centre experience, ergonomist
- Method / process: CRIOP Part 1 (Layout section), checklist evaluation using the Control Room Layout section of this methodology

Workstation Layout and Dimensions

Verification

- Input material: regulatory documents regarding Workstation Layout and Dimensions (ISO 11064)

- Team: personnel with control centre experience, ergonomist
- Method / process: comparison of the design specifications against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: design documentation, mock-up or VR model
- Team: personnel with control centre experience, ergonomist
- Method / process: CRIOP Part 1 (Layout section), checklist evaluation using the Workstation Layout section of this methodology

Design of Displays and Controls

Verification

- Input material: regulatory documents regarding displays and controls (ISO 11064), task analyses
- Team: personnel with control centre experience, human factors / cognitive engineering specialists
- Method / process: comparison of the design specifications against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: design documentation, drawings, simulations, task analyses
- Team: personnel with control centre experience, human factors / cognitive engineering specialists
- Method / process: CRIOP Part 1 (Control and Safety Systems); checklist evaluation using the Displays and Controls section of this methodology.

Environmental Design

Verification

- Input material: regulatory documents regarding Work environment (ISO 11064), design documentation
- Team: personnel with control centre experience, health and safety specialists
- Method / process: comparison of the design specifications against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: design documentation, drawings, VR models
- Team: personnel with control centre experience, health and safety specialists
- Method / process: CRIOP Part 1 (Environment section), checklist evaluation using the Working Environment section of this methodology.

Operational and Managerial Requirements

Verification

- Input material: regulatory documents regarding Operations and Managerial Requirements (ISO 11064), task analyses, planned division of responsibilities, function allocations
- Team: personnel with control centre experience, managers
- Method / process: comparison of the design specifications against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: design documentation, planned division of responsibilities, task analyses, function allocations
- Team: personnel with control centre experience, managers
- Method / process: CRIOP Part 1 (Job Organisation section); checklist evaluation using the Job and Organisation section of this methodology.

Training

Verification

- Input material: regulatory documents regarding Training, training needs analyses, task analyses
- Team: personnel with control centre experience, training specialists
- Method / process: comparison of the training plans against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: training plans, training needs
- Team: personnel with control centre experience, training specialists
- Method / process: CRIOP Part 1 (Training section); checklist evaluation using the Training section of this methodology.

Procedures

Verification

- Input material: regulatory documents regarding Procedures, procedure requirements
- Team: personnel with control centre experience, auxiliary personnel who occasionally work in the control centre (e.g., ECC), procedures specialists
- Method / process: comparison of the procedures requirements against the regulatory documents, comparison of the conceptual and detailed design against the specifications

Validation

- Input material: procedure requirements, procedure plans, draft procedures

- Team: personnel with control centre experience, auxiliary personnel who occasionally work in the control centre (e.g., ECC), procedures specialists
- Method / process: CRIOP Part 1 (Procedures section), checklist evaluation using the Procedures section of this methodology.

Step 11: Collect Operating Experience

Purpose

The purpose of collecting operating experience is to continue checking on the validity of a design throughout its lifespan.

Introduction

The design team's work does not finish on the day that a system is built and becomes operational. It is good practice to follow up a project with a review of operational successes and shortcomings. Operating experience can be looked at as validation in real life (see Step 10) because validation is concerned with showing whether something actually works.

The issues discovered when operating experience is collected, and the lessons learnt, give a way to correct or improve the current system design, and to influence future upgrades and changes. Broad-based experience reviews have typically been performed as part of regular engineering disciplines. The objective of including the review here (in these guidelines) is particularly to look for *ergonomic/human factors* successes and shortcomings. For the human factors parts of a project, the intention here is to have a more focused review that concentrates on human factors issues and experience.

The record of an operating experience review is a valuable resource. It can be used to make operational adjustments, and in future projects that affect the same or related things. Information of this kind is difficult to obtain at design stage. For instance, it is difficult to be sure that a design results in acceptable workloads unless a full-scope simulator was available at design stage, or operating experience from previous, related projects is available.

The issues found by a review of operating experience need resolving in some way (even if the decision is to make no changes). These resolutions can require change in several areas, such as:

- automation,
- function design,
- detailed equipment design,
- training, and
- procedures.

The changes could range from minor alterations to an existing system, or changes in operational use, to a decision that an upgrade or new system is needed.

Existing reviews of operating experience, from related projects, can also help throughout new design projects, by suggesting areas that later need reviewing in the design, when it is more fully developed. See Step 1 for advice on how to use operating experience at the beginning of projects. For example, an operating experience review (OER) can:

- help in the selection of scenarios to be used in validation,
- suggest performance measures when the design is tested (i.e., some aspect of performance that was identified in an OER as problematic).

Objectives

Operating experience is collected for several reasons:

- *safety* — to identify human factors issues related to safety,
- *performance* — to identify human factors issues related to performance,
- *design goals* — to find out whether existing systems meet their objectives, and
- *continuous improvement* — to ensure that these safety and performance issues are addressed, either in new designs or upgrades, or by corrections to existing systems.

Regulatory Requirements

- Emergency Preparedness Regulations §§ 17–19
- Safety Regulations §§ 14 and 17
- SAM Regulations §§ 17 and 31

Other Standards and Guidance

- Human Factors Engineering (HFE) Insights for Advanced Reactors Based upon Operating Experience. Higgins, J, and Nasta, K. (1997)
- *Ergonomics in Process Control Rooms. Part 2: Design Guideline*. International Instrument Users' Associations (1998)
- ISO/FDIS 11064-1. International Standards Organisation (1999a)

Information Sources for the Reviewer

Diverse documentary sources should be used in an OER, for instance:

- event reports from operators;
- operators' internal memoranda;
- operating surveys and interviews;
- experiences from exercises;
- logs and systems for transfer of experience;
- accident records;
- occurrence of health problems and work-related illness;
- evaluations of organisational matters;
- surveys of the working environment, including psychosocial factors;
- analysis of, or reasons for, shutdowns;

- experiences with alarm systems;
- experiences with maintenance and operational safety;
- modifications to technical specifications.

Review Guidance

1. Were suitable methods used for collecting operating experience?

Field observations, interviewing (see question 2), and any other systematic methods can be used.

2. Was the collection of experience comprehensive?

The design team should generally try to discover operating experience relevant to all steps of human factors design work from phase A to D. See also questions 5 and 6.

3. Did the review include interviews with operations staff?

There should be interviews with operations staff to find out good and bad points of the system that was designed in the previous steps. The interviews should be structured around both plant operations and human factors topics, although the objective in both cases is to look for human factors successes and shortcomings.

- *Human factors topics* — CCR operators may find it easier to talk about specific issues, rather than abstract concepts like function design, such as:
  - alarms and how they are shown;
  - displays;
  - controls and automation;
  - information-processing systems and job-aids;
  - communications with other personnel and organisations;
  - procedures, training, staffing and job design.
- *Plant operations* — operations staff may find it easier to give useful information structured around particular incidents or parts of their job, for instance
  - normal plant modes, e.g., steady state operation, start-up, shutdown, isolation for maintenance, well testing, well intervention;
  - instrument failures;
  - failures of equipment provided for control centre operators, e.g., alarm systems, screen displays, communications systems
  - transients and process disturbances;
  - operator actions to shut down and similar transitions between operating modes.

Note: the SAM Regulations §§ 17 and 31 refer to evaluation of the working environment at the workplace, and to transfer of experience in relation to the working environment.

4. Did the review include information about incidents and accidents?

Audits of operations are quite likely to include detailed analyses of incidents and accidents. These highlight failures and breakdowns that have occurred. Such audits can be a useful source of information in an OER. In addition, smaller incident reports can be a very valuable resource.

Unless there is a well-developed recording system in place for near misses, these will be very difficult to find out about. Only the major incidents will be recorded. Even so, near misses and minor incident reports are useful if they can be found, if only because there are many more of them to study.

Certain events may reveal that there is insufficient time for a series of operator actions, or that workload on individual operations staff is too high in some circumstances. This may point to the need to develop time criteria for safety-related operator actions or a reconsideration of automation.

Note: the Emergency Preparedness Regulations, §§ 17, 18, 19 refer to maintenance and furtherance of emergency preparedness, and systems for transference of information about emergency preparedness. This information could also be used in an OER.

Note: the Safety Regulations § 14 refer to follow-up of circumstances of significance to safety.

5. Was there an analysis of operational successes and shortcomings?

For human factors, the review should analyse:

- human performance problems,
- sources of human error, and
- design elements that support good human performance.

These features should be documented. The range of issues that could arise is very large, and will be different from project to project. Here are some examples.

- *System integration* — the quantity of information may be too great during transients or changes of operational mode. If only parts of a control room have been upgraded, there may be duplicated information, incompatibly formatted information, or even contradictory information. Poor design can cause operator error, information overload and unwanted distractions.
- *Changes in control modes* — during transients, CCR operators may suddenly be required to take control of systems that are normally automated, causing unacceptable workload. The design may not give sufficient support for this.
- *Extrapolations from information* — CCR operators may be required to do their own calculations, make inferences from displayed data, mentally compile measurement trends, etc., in ways that could easily be done by automation.
- *Test and maintenance* — the design may not allow for things like spurious alarms caused by maintenance, deactivated alarms, auxiliary operator support for maintenance.
- *Alarms* — there may be problems with the quantity of alarms, floods of alarms during incidents, and prioritisation. Operators may become overloaded during certain events that they do not silence or acknowledge alarms.

- *Controls and displays* — new computer-based displays may be difficult to customise, change or upgrade. There may be unacceptable response-time delays when a display refreshes live data or calls up a graphical display. These delays may not be operationally acceptable, or may cause the CCR operator not to use certain displays as much as the designer intended.
- *Communications* — there may be insufficient communications between the CCR and other staff on the installation. Background noise in the CCR may be higher than anticipated, due either to equipment noise or to people in the control suite. There may be plant locations where auxiliary operators cannot be paged due to background noise or incomplete coverage.
- *Procedures* — there may be insufficient space, too much cross-referencing, awkward physical management and poor maintenance of procedures. Paper procedures may not be well integrated with computerised tasks and support systems.
- *Training* — there may be discrepancies between the training received and how the job is done in practice. Operators may feel that the training they received did not provide them with adequate skills and knowledge to do the job.
- *Advanced instrumentation and control* — manual tracing of faults in 'advanced' systems may be more difficult and time-consuming than in traditional hard-wired systems. There may be no operator interface for testing and diagnosis of computerised C & I. There may be spurious trips of equipment, sporadic failures. Operator confusion may be caused when instruments fail or lose power.

See question 7 for suggestions on how these issues might be resolved.

6. Was the analysis comprehensive?

The analysis should try to relate the issues found in operating experience to each of the design steps in the project that came before the review (Steps 1 to 9). This will allow resolutions of the issues to be formulated more easily, and it will be clearer in future work when to apply the resolutions. These resolutions can then be used in the way suggested in question 7.

7. Were there clear resolutions resulting from the successes and shortcomings that were identified?

It should be decided what to do about each of the identified issues. Some of these resolutions may require operational adjustments. Others may have implications for future designs and related projects. Whatever the resolution, it needs to be clear for users of the experience review (including staff making operational adjustments to a current system, external reviewers, staff of future projects) what the resolutions are, what future actions are recommended, etc. The resolution of issues could potentially relate to any of the previous design steps, for example, function allocation, detailed equipment design, procedures and training.

The resolutions will vary greatly from project to project. Here are some examples based upon question 5:

- *System integration* — eliminate duplicated alarms; increase automation during changes between operational modes and other times of peak operator workload; consider displays that integrate information from different systems
- *Changes in control modes* — consider further automation; design any future upgrades in an integrated way.
- *Extrapolations from information* — provide processed and calculated values needed by operators; integrate derived information with other displays.

- *Test and maintenance* — design systems so that they can be periodically tested without creating incidents; build in test connections and instruments.
- *Alarms* — consider computerised alarm systems; make sure that the alarm systems support all the things that CCR operators need, including rapid detection and pattern recognition, situation awareness, availability to the entire CCR crew, ability to navigate within computerised alarm displays.
- *Controls and displays* — ensure that there is a way to upgrade software in the field; increase graphics and display processing power; ensure that future design processes are thoroughly planned and use appropriate guidance documents.
- *Communications* — ensure that communications requirements are considered at design stage; increase communications coverage; reduce access of extraneous personnel to the control suite.
- *Procedures* — consider computerised procedures; introduce a better system for updating paper procedures; rewrite procedures to reflect how CCR operators actually work; increase operator workspace.
- *Training* — review how the tasks to be trained are selected and review the training system using the questions in Appendix 9.8A.
- *Advanced instrumentation and control* — make sure that testing and maintenance are covered in new designs; provide automated test equipment; make sure that new systems are subject to software V&V

Note: the Safety Regulations § 17 refers to registration and follow-up of incidents and damage.

Table 11. Checklist for Operational Feedback

Review Topic	**Comments on quality of evidence**
1 Were suitable methods used for collecting operating experience?	
2 Was the collection of experience comprehensive?	
3 Did the review include interviews with operations staff?	
4 Did the review include information about incidents and accidents?	
5 Was there an analysis of operational successes and shortcomings?	
6 Was the analysis comprehensive?	
7 Were there clear resolutions resulting from the successes and shortcomings that were identified?	