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GUIDELINES FOR INSTRUMENTATION PROJECT ENGINEERING

(PROJECT STANDARDS AND SPECIFICATIONS)

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SCOPE

This Project Standard and Specification provides guidelines on the engineering processes that go into completing Control and Instrumentation (C & I) projects.

INITIALISATION PHASE

User Requirements and Scope of Work

1. Scope

   Determine the client's requirements for control and instrumentation and write them up for reference during the project.

2. Input

   Discuss with the project leader and client the requirements in terms of the checklist detailed at the end of this procedure to ensure that all items relating to the User Requirements and Scope of Work are covered. The Project Brief must also be studied to ensure its requirements are covered.

3. Process

   Determine the requirements in conjunction with the client. The information should be gathered by studying the Project Brief and/or discussions with the client.
   It must then be analyzed to ensure that it is complete and consistent.
   A checklist of items to be evaluated is attached to this procedure.

4. Output

   Produce a document entitled User Requirements and Scope of Work. It is circulated to all interested parties in the project. They will respond with their comments which are to be incorporated into a revision of the document.

5. Approval

   The document must be approved by the client and the discipline Project C&I Engineer once the revisions are complete.

Checklist of User Requirements and Scope of Work

The following is a checklist of the factors to be considered:

1. Systems Required
   - plant control and instrumentation

- monitoring systems
- telephone systems
- intercom systems
- radio systems
- networking for voice and data
- CCTV
- access control
- fire detection and protection
- security systems
- vehicle location/tracking/condition monitoring

2. Services Required

- feasibility study
- conceptual design
- estimating
- simulation
- design
- software
- specification
- enquiries
- orders
- installation
- site supervision commissioning

3. Timescales

- project program

4. Process Control Requirements

- type of plant: material (gold, coal, etc.); process (CIP, rail loading etc.); scale (pilot, sample, test, production)
- description of process operation
- flow sheets
- cost sensitivity of the project
- special process requirements e.g. hazardous processes, explosive and/or toxic and/or corrosive.
- level of automation required
- level of instrumentation required
- new, extended, modified, upgraded or refurbished
- production factors, e.g. productivity index, plant availability/utilisation, allowable downtime

- description of control facilities (i.e. degree of functionality in terms of logging, reporting, diagnostics, optimization, maintenance, simulation capabilities, etc.) to be catered for now or in the future.
- number and quality of plant operators to be catered for (level of understanding of the process, equipment and control systems)
- plant infrastructure requirements for air, water supplies.

5. Plant Control Philosophy

- type of control system required: e.g. hardwired, PLC, distributed control system, supervisory system
- degree of centralisation/de-centralisation
- plant geographical layout and control nodes
- control system architecture
- connection to management level systems
- local/remote control of machines or processes
- connection to other plants, areas or systems
- system response times
- reliability
- intellectual property rights

6. Equipment and Design Requirements

- standardization/conformity with existing systems/equipment
- equipment preferences non-preferences
- compatibility with existing equipment
- fire retardancy of cables
- client preferences for specifications
- preferred design standards, drawing symbols and numbering systems

7. Spare Capacity Requirements

- possibility of future extensions (plant areas and/or streams) and to what extent it must be allowed for in the design
- supervisory system expansion
- plc expansion
- tags, database
- control cubicle expansion
- additional instrumentation
- spare space requirements (i.e. instrument rooms, cable racks, etc.)
- spares policy, commissioning and maintenance (project, client supply)

8. Safety Requirements

- hazardous areas and classification
- personnel and equipment protection circuitry

- earth fault/leakage limitation requirements
- security/entry restriction requirements
- fire protection requirements (cables, seals)

9. Environmental Considerations

- environmental sensitivity of project
- altitude
- ambient temperature range
- humidity
- corrosion, in air/water/ground
- lightning activity
- pollution, dust

10. Power Source (Liaise with Electrical Engineer)

- reliability of power supply
- stability or quality of power supply (voltage, frequency, harmonics)
- interruptions to raw mains supply - frequency and duration
- provision of clean, secure supplies, e.g. UPS, CVT
- required duration of back-up supplies for instrumentation and computer systems
- lightning/surge protection practice
- earthing requirements

11. Local Infrastructure

- availability of skilled manpower
- availability of locally manufactured equipment
- availability of spare parts
- availability of communication infrastructure
- availability of suppliers and contractors
- need for special work permits, security clearances - central, regional and local government requirements
- applicable standards and authorities

12. Control and Instrumentation Room Requirements

- number of occupants and facilities
- temperature requirements
- humidity
- ventilation and air filtering requirement
- vibration
- static control
- cable management e.g. ducts, raised floor
- lighting

13. Quality Assurance Requirements
    - QA philosophy
    - identification of critical equipment
    - plant life expectancy
14. Site Layout and General Arrangement Drawings
    - obtain copies of above diagrams, if available
15. Training and System Development Requirements for Operating and Maintenance Staff
    - services required
    - nature of facilities required
    - simulation needs

CONCEPTUAL ENGINEERING

Conceptual Design

1. Scope

   The Conceptual Design gathers sufficient information on the job to allow it to be cost and planned. Develop alternative designs.

2. Input

   The User Requirements and Scope of Work, Block plan and Flow sheets are used to do the conceptual design.

3. Process

   The input documents are analyzed to yield information on the following:
   - control system configuration
   - number and size of the control nodes
   - types and number of instruments
   - instrumentation and control equipment geographical layout.

4. Outputs

   In order to provide estimates for the project the following documents are to be produced:
   - preliminary instrument schedule
   - preliminary I/O schedule
   - preliminary Control System Architecture Block Plan

5. Approval

The Project C&I Engineer is to approve the documents.

Design Scope

1. Scope

   The design scope defines the work to be done by the C & I Department for the client and the documents that will be produced.

2. Inputs

   The inputs are the User Requirements and Scope of Work, and the Conceptual Design. Hold meetings with the client and Project leader to discuss the requirements.

3. Process

   Once the scope of work is known, the C & I engineer can make proposals on what services are to be included and how the work is to be done.
   Where the client prefers to do portions of the work or wants to be involved in, or approve, certain portions of the work it is advisable to draw up a responsibility schedule. The responsibility schedule defines which deliverables are to be produced by the various parties.

4. Outputs

   The Design Scope will define the specific services to be provided and a list of the output documents (or deliverables) that will be produced.
   Services to be provided may include:
   - Plant Simulation
   - Engineering
   - Enquiries, Adjudication and Orders
   - Design
   - Software
   - Operator Training
   - Site Supervision
   - Commissioning

   Output Documents may include:

   - User Requirements and Scope of Work
   - Preliminary Design
   - Design Scope
   - Class I Capital Budget and Reimbursable Estimate
   - Basic Project Requirements for C & I Design, comprising a compilation of the above documents
   - Conceptual Design

- Class II Budget
- Specifications
- Detail Design Drawings
- Functional Specification
- Software Documentation
- Enquiries and Adjudications
- Class III Budget
- Progress Reports
- Class IV Budget
- As Built Documents
- Close Out Report

5. Approvals

   The Design Scope needs the approval of the Project CIE Engineer, who will discuss the document with the CIE Manager before it is submitted for client approval.

Class I Estimates and Budgets

1. Scope

   Approximate costs for the proposed C & I work are required early in the project. Class I estimates are the lowest level of accuracy produced for projects. They are "Order of Magnitude" estimates where the target accuracy is dependent on the data available. The range of accuracy is to be indicated on the estimate. Refer to the Project procedures for the detailed definition of Class I estimates.

2. Inputs

   The Conceptual Design gives the capital items to be purchased. The Design Scope document details the work to be done.

3. Process

   Capital Equipment costs are estimated by obtaining current budgetary quotes and comparing with actual costs, suitably escalated from past projects. The C & I costs must be checked against the total capital value of the project.
   Standard rates for design drawings multiplied by the number of drawings required allows the design reimbursable budget to be calculated. Similarly the engineering and software work needs to be estimated and hours put to the work. Once this is done it must be compared with actual hours used on similar past projects. The cost of the reimbursable hours needs to be checked as a percentage of the capital value of the C & I costs.

4. Outputs

   Standard estimate sheets are available for reimbursable man-hours and capital costs. These are completed, showing the work to be done, the level of accuracy and the associated costs.

5. Approvals

   It is essential that the reimbursable estimates for all large projects are signed by the CIE Manager in addition to the Project C&I Engineer. Capital cost estimates will be discussed by the Project C&I Engineer with the CIE Manager.

Program

1. Scope

   A provisional program of work is drawn up to ensure that the C & I work can be scheduled within the time-scales required by the client.

2. Inputs

   The number of reimbursable hours has been determined in the Class I estimate. The project plan will give the approximate time-scales available to do the work and the list of required deliverables.

3. Process

   Discussions with the planner around the above documents allow the C & I work to be scheduled. The C & I Engineer will then estimate how many people will be required and when they will be needed. This will allow a program of work to be defined in conjunction with the project planner. The impact on the department must be considered.
   The program must show all the project phases including capital equipment phasing to ensure that the work can be done within the required time-scales. The work breakdown should be shown in terms of the deliverables to be produced.
   Different levels of detail are normally needed (Level 1, 2, 3) to suit the requirements of the overall project program.

4. Output

   This work is done in conjunction with the Project Planner and the final output is generated by him. It remains the responsibility of the discipline engineer to ensure the accuracy of his portion of the work.

5. Approval

   The C & I Engineer must co-ordinate the work with all sections within the C & I Department as well as the Project Leader, other departments and the client.

Project Reports

1. Scope

   Project reports give information on the status of the project for information, management and control of actual project progress against planned progress.

2. Inputs

   The project program identifying the major milestones and the main C & I activities.
   The approved project estimate sheets for reimbursable and capital expenditure, including a detailed listing of the documents to be produced, hours budgeted and equipment to be purchased.

3. Process

   Keep records of time spent for all C & I persons working on the project.
   Keep records of documents produced together with time spent. This must include enquiries and orders generated, and the associated values.
   These records must be kept from the start of the project to determine cumulative values to date. Sources of information for these records are from individual's time sheets, drawing registers, procurement schedules, database systems.
   Project reporting requirements may vary in detail from one project to another depending on the project manager requirements. Reporting will generally be required to cover the project to date, year to date and the last month.
   Reports will generally be required to provide status on the following:
   - Reimbursable expenditure, which should include for engineering, software and design. Actual hours and monetary values should be shown for each category. A combined cumulative figure against budgeted values is also needed.
   - Document production including engineering drawings and software. A list of the drawings should be produced which shows the number of sheets and their size. It should show estimated budget hours, the remaining hours and the percentage completion.
   - Capital expenditure. Enquiries and orders dealt with during the reporting period should be noted, the latter with the order values compared with the

estimates. Cumulative listings for the project to date will show overall progress against budget.

4. Outputs

   Produce reports on project progress on:
   - Reimbursable expenditure
   - Capital expenditure
   - Drawing production
   - Engineering design
   - Software design
   - Project activity progress

   These documents are to be circulated as required.

5. Approval

   The Project C&I Engineer will determine which of these need approval before circulation.

Design Estimate/Proposal/Tender

1. Scope

   The documents produced during the Conceptual Engineering phase of the project need to be collated into a single document at the end of this phase. This document commits the C & I Department to complete the agreed and described scope of work to an agreedprogram at an agreed cost.

2. Inputs

   The inputs are:
   - Users Requirements and Scope of Work
   - Preliminary Design
   - Design Scope
   - Budgets and Estimates
   - C & I program

3. Process

   The above documents are collated and checked for consistency. A covering note is produced to briefly describe the deliverables, exclusions and information to be received from the client.

4. Output

   The collated document is entitled "Proposal/Tender for Control and Instrumentation for the Project. It contains the sections listed above under Inputs viz:

- User Requirements and Scope of Work
- Preliminary Design
- Design Scope
- Budgets and Estimates
- C & I program

5. Approvals

   This document must be approved first by the CIE Manager, Project leader and then by the client. It may form part of an official proposal or tender submitted to the client.

FEASIBILITY ENGINEERING PHASE

Feasibility Design

- Scope

  The conceptual design will be reviewed and refined. Where alternative conceptual designs exist, the most appropriate design will now be selected and developed further to test its feasibility in the project.
  Problem areas defined at the feasibility stage will be resolved. Numbers and types of instruments and controllers will be identified, together with approximate sized where significant e.g. input/output quantities for PLC, line sizes for control valves and flow meters. The resultant design will be formally reviewed, and a class II estimate prepared.

- Inputs

  Documents prepared during the initialization and conceptual engineering phases should be reviewed, together with any preliminary drawings and the class I estimate.
  The User Requirements and Scope of Work should be reviewed. Any changes from the initial feasibility study should be noted carefully.
  A copy of the project timetable should be obtained and reviewed to ensure that it is practicable and that the necessary staff and resources can be obtained when required.
  Discussions with the client staff and engineers from other disciplines will continue throughout this phase, both formally and informally as necessary.
  A copy of the draft Block Plan should be obtained from the project civil or mechanical engineer. Ensure that he sends you revised copies as design proceeds.
  A copy of the equipment list should be obtained from the Project Engineer, and updated regularly.

A copy of the drive list should be obtained from the project electrical engineer, and updated regularly.
A copy of the Work Breakdown Structure should be obtained from the Project Leader. This may affect the numbering of drawings as well as the numbering of equipment. It may also affect reporting and accounting procedures if the client requires detailed information for each area.

- Process

The activities listed here should be performed in the sequence suggested where possible. Some or all of these activities may continue for sections of the plant while delays are encountered in obtaining information for the remaining sections.

1. Flowsheets

   Preliminary flow sheets will be obtained from the client and/or the Process Engineer. These should be fully drafted and completed by the C & I Design Office using the information provided and the standard drawing procedures.

2. Piping and Instrumentation Diagrams ("P&IDs")

   P&IDs should be drafted in consultation with the client and/or the Process Engineer, using the flow sheets as a basis. The Design Office shall ensure that the drawings conform to the C&I Department standards. These drawings may undergo several revisions during the conceptual phase, but by the end of the phase they should show the following information:
   - All items of equipment, with equipment numbers
   - Equipment list
   - All instruments, with tag numbers
   - All drives, with interface numbers where appropriate
   - Preliminary pipe sizes and material codes for major lines

3. Instrument Schedule

   A preliminary instrument schedule can be prepared from the information show on the P&IDs. Instrument types should be indicated, but not vendors.

4. User Functional Requirements

   User requirements should be discussed with the client. This should include:
   - Number and location of control room(s)
   - Number of operator stations required at each control room
   - Areas of plant to be controlled from each location
   - Local operator stations - if required e.g. barring control for a mill

- Any special requirements: speed, redundancy, hardware, network, interface to Management Information System(s), future expansion
- Level of automation required: interlocking, sequencing, full automation
- Data storage and retrieval required: reporting, trending, and archiving.

5. Input/Output Schedule

   A preliminary input/output schedule can be prepared for each logical plant area from the information shown on the P&IDs.

6. Control System Configuration

   A preliminary control system configuration can be prepared from the above information, taking into account such factors as:
   - logical and physical plant areas
   - location of MCCs/substations
   - location of control rooms and operator stations
   - user functional requirements
   - input/output counts

7. Monitoring of costs and progress

   Monitor costs and report in accordance with Procedure above.

   Outputs

   The following outputs will be produced, all in preliminary form except the flowsheets:
   - Flow sheets - complete and approved by the client
   - P&IDs
   - Instrument schedule
   - User functional requirements
   - Input/output schedule
   - Control system configuration

   Approval

   The above documents will need approval from the Project C&I Engineer prior to the Design Review.

Feasibility Design Review

1. Scope

   The feasibility design should be formally reviewed before proceeding to detail design. The purpose of this review is to check that:
   - the client's defined requirements are met

- the design conforms to department standards
- appropriate technology is being use.

2. Inputs

   The following inputs are required:
   - P&IDs
   - User Functional Requirement
   - Control system configuration
   - Black plan

3. Process

   The review will be arranged by the Project C&I Engineer, or the responsible Project Engineer for small projects. The review panel will consist of the senior engineers in the Department, together with client representatives.
   Copies of the input documentation listed above should be issued to all participants a week ahead of the meeting, together with a brief agenda listing the main areas/points to be covered.
   The nominated chairman of the review panel will ensure that all points are covered and that notes are kept of any changes required. A summary report should be prepared by the C&I Project Engineer and issued to the review panel and the client to confirm that all matters raised have been adequately dealt with.

4. Outputs

   - Final feasibility design documentation
   - Summary review report

5. Approval

   The Project C&I Engineer will approve the output documentation and forward it to the client. A copy of the review report will also be sent to the CIE Manager if he was not present at the review meeting(s).

Class II Estimate

1. Scope

   The purpose of the cost estimate from the conceptual design phase is to provide a working budget for the detail design, together with an indication of the total cost of the project. This is a preliminary estimate and is defined as a Class II estimate of target accuracy - 15% to +25%.

2. Inputs

The input phase of this process is the collation of the relevant information from the conceptual design documentation.
The following is a checklist of the input required:

a. Conceptual Design Drawings
   - Process flow sheets
   - Plant general arrangement drawings
   - Preliminary Instrument Schedule
   - Preliminary P&IDs
   - Preliminary Control System Architecture
   - Preliminary Cable block diagram

b. Functional Requirements
   - Process description
   - Control philosophy
   - Plant start-up sequences
   - Plant shut down sequences
   - Plant run time sequences and interlocking
   - Advanced control requirements

3. Process

The process is the establishment of the costs of capital, detail design, software development, construction, installation and commissioning.
The following is a checklist of process functions to be included:

a. Capital Costs (by budget Quotation)
   - Instrumentation
   - PLC system & system software
   - SCADA system (including software package)
   - Networking hardware

b. Capital Costs (by Estimation)
   - Cabling and racking
   - Cabinets & junction boxes
   - PLC application software development
   - SCADA system configuration (including mimics, data base, reporting etc)

c. Detail Design Costs (by Estimation of man hours)
   - Simulation
   - Final flowsheets
   - Design P&IDs
   - Instrument schedule
   - Instrument data sheets

- General arrangement drawings
- Wiring diagrams
- Cable block diagrams
- Cable schedule
- Drive loop diagrams
- Instrument loop diagrams
- Application software specification
- Software development and coding
- PLC specification
- Supervisory system specification

d. Installation Costs (by Factoring)
   - Instrumentation
   - Control system
   - Supervision of construction

e. Training Costs (by Estimation)
   - Operator training by simulation
   - PLC training - hardware and software
   - SCADA system configuration training

f. Commissioning Costs (by Estimation of man hours)
   - Acceptance testing
   - Software testing by simulation
   - Process commissioning software support

g. Project Engineering Cost (by Estimation)
   - Preparation of specifications and enquiries
   - Adjudication of tenders
   - Processing of procurement documentation
   - Project planning
   - Supervision of detail design
   - Project meetings and administration
   - Project reporting, including "close-out" report

h. Contingencies (by Calculation)
   - To be completed on the basis of standards

All of these factors are evaluated and cost for summarizing in capital cost and reimbursable cost estimate spreadsheets. The format of these has been formalized in_CIE forms for offer to the client as an existing standard. However, it is always advisable to agree formats with the client at initialization phase.

4. Approvals

The final class II estimate will be approved:
- Project cost < R500 000 - Project C&I Engineer
- Project cost > R500 000 - CIE Manager

Before submission to the client or project co-ordinator.

DETAIL ENGINEERING PHASE

Design Simulation

1. Scope

   The scope of simulation for the detail design phase is based on the level of simulation desired by the client. This scope can vary between simple "mass balancing" process flow sheets for the evaluation of alternative processes and full dynamic simulation of all or part of the process for plant "operability" studies.

2. Input

   The input to simulation is the feasibility design flow sheets, the relevant models parameters and process data from our own sources; client assumptions and laboratory test results.
   The level of input required is directly related to the level of simulation required to meet the client's requirements, but is likely to include the following:
   - Conceptual Design Flow-sheet (either manual or simulation)
   - Conceptual Mass Balances
   - Unit Process Models
   - Unit Process design parameters (by assumption and/or laboratory results)
   - Ranges of operating parameters to be evaluated
   - Process control philosophies
   - Operating strategies
   - Functional requirements

3. Process

   The processing phase is the development of "operable" process flow sheets with an agreed level of process control implemented. Different process and control alternatives are evaluated as a pre-requisite for detail C & I design.
   This work is generally carried out as an iterative process with the process engineer from the project and includes input from both the C&I Engineer and software engineer.

4. Outputs

The outputs of the simulation are approved process flow and instrument diagrams (PF & IDs) functional specifications and "operability" reports.

5. Approvals

   These documents must be approved by the client project management as the basis for full detail design and the software quality assuranceprogram.

Equipment Types and Definition

1. Scope

   Define the characteristics and requirements for every instrument and control function on the plant. Ensure that they will be fit for the purpose for which they are required.

2. Inputs

   Input documents are:
   - Flowsheets
   - P & IDs
   - Functional Specification/User Requirements
   - Control system configuration drawings
   - Cable block diagrams
   - Cable schedules
   - I/O schedules
   - Instrument installation drawings
   - Mechanical general arrangement drawings of the plant
   - Mechanical detail drawings of selected items of equipment
   - Electrical drawings, as required, e.g. MCC layouts, drive controls
   - Civil and Architectural drawings, as required
   - Simulation data
   - Close-out reports for relevant, recent, similar project
   - Instrument specifications
   - Instrument data sheets
   - Reports from research organizations
   - The literature
   - Manufacturer’s information

   Use only the latest revisions of these documents and up to date information. Communicate both informally and formally with other project disciplines to gather and exchange information.